SHAPING TEXTILES:
An investigation from two-dimensional surfaces to three-dimensional spatial organisations

Gaëlle Mazouer

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Faculty of Design, Architecture and Building

University of Technology Sydney

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Gaëlle Mazouer

Date:

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PREFACE

By their history and daily omnipresence, textiles are both the vectors of traditions and the grounds for the latest research in material innovation. A broad and practical discipline, textiles encompass a quantity of materials, structures, processes and applications. Additionally, diverse technologies (from crafts to industrial) are used in the creation of textiles.

During the first years of my studies, I acquired essential knowledge in material construction. An international French student, I graduated with a Bachelor of Textile Design from La Cambre, Belgium. My studies were based in the exploration of technical skills in the textile making processes; a holistic approach to textile production was adopted. Exploration of materials and fabrication techniques (including knitting, weaving, printing and dying) led each practical project to an understanding of potential of structure and form making in textiles. Experimentations and explorations of material through textures, structures, rhythms and colours is the purpose of a textile designer's work. These processes are a means for both self-expression and for specific research in design with the aim of practical application.

Previous undergraduate investigations on textile history have reviewed influential designers such as Anni Albers (1899–1994). A particular emphasis has been placed on the importance of Albers' work due to its impact on the theory and practice of weaving. Albers is considered an iconic textile designer with a strong concept of the 'truth of material'. She built this concept in the 1920s while studying and teaching at the Bauhaus school[1]. During this period, studies at the Bauhaus took the form of practice-based experimentation. It is this very approach that gave rise to Albers' concept of the 'truth of material', a concept that rests on the idea that artists and

1 The Bauhaus school, based in Weimar, Germany, operated from 1919 to 1933.

designers should follow the characteristics of materials and 'push' their capabilities throughout the creative process. As Albers (cited in Danilowitz 2000, p. 72) states,

> If a sculptor deals mainly with volume, an architect with space, a painter with colour, then a weaver deals primarily with tactile effects. (...) Qualities of the inner structure are as much part of a textile as are effects of outer tactile surface. The structure of a weaving, as well as the fibers chosen for the work, can bring about an interesting surface. There is an intricate interplay between the two. A knowledge of textile construction is thus essential for matiere effects, as it is for the organization of a weaving as a whole.

Unquestionably, the texture of a textile cannot be separated from the behaviour of its structures. From the choice of raw material to the final design outcome, touch perception is constantly present during textile fabrication; textiles are experienced through the senses, thus, tactility is a major part of the process. Bristow (2012, p. 45)[2] notes that the repetitive gestures and actions involved in making a piece, generates a close relationship between the maker, the machine and the material. In the experimental textile making processes, the maker's body and its motions play a fundamental role in the construction of textile. The maker's control over their tools in building the structure produces textured effects.

A study on the influence of Albers' thoughts and methodologies on textiles and design formed the basis for my undergraduate research on weaving techniques. My previous investigations culminated in a practical collaboration with 'Masters of Linen: the European confederation of Linen and Hemp', which aimed at promoting linen in design. The initial stage of this project, entitled The Linen Project, focused on the examination of linen materials and their properties. Following a comprehensive analysis, this study explored the production of linen from raw fibres to cloths and experimented with weaving techniques. The focal point of The Linen Project was the partial de-construction of structures into their components with the intention of uncovering how they had been assembled.

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2 Maxine Bristow is an artist and academic. Her paper, 'Continuity of Touch—textile as silent witness' was originally presented at the 'Repeat Repeat' conference at the University of Chester in April 2007.

Figure 1. *The Linen Project*, weaving structures

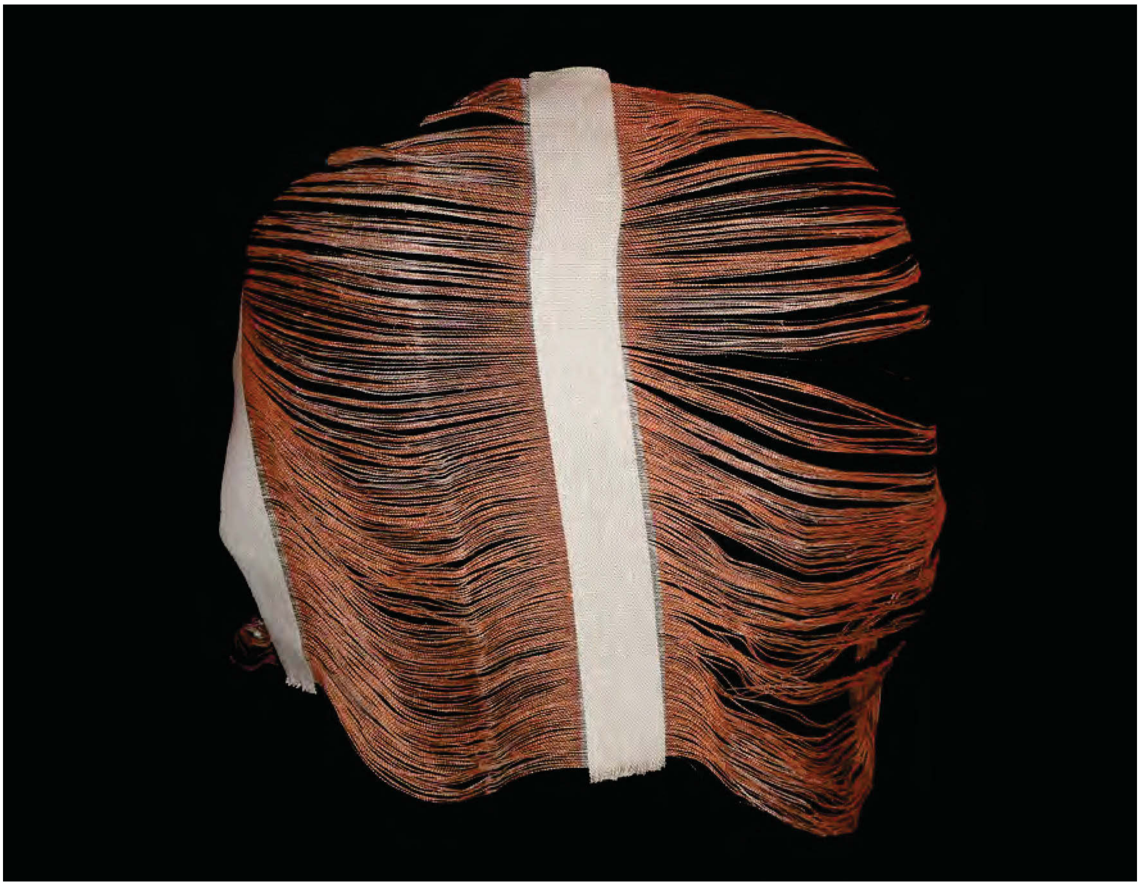

Figure 2. *The Linen Project*, weaving structures

The knowledge gained from this study was instrumental in my developing an understanding of textile construction. The Linen Project, as illustrated in Figure 1 and 2, included manipulations of woven textiles and explored the possibility of textiles addressing and communicating the human form. As Hamlyn (2012, p. 149) states,

> Fabric acts to conceal and cover objects and persons, while at the same time, disclosing them - hinting at their presence (...) Fabric is malleable. It lends itself to wrapping, draping, and swathing. It restricts direct access to the naked object, but it also has the ability to suggest, enhance and draw attention to what it covers over and adorns.3

As shown in Figure 1 and 2, the work within the structures aimed at visually associating weaving and the human silhouette. Different types of 'body skeletons' were created through the use of contrasted tight and loose materials. Consequently, the networks of yarns highlight the features and proportions of the body's form while challenging the viewer's perception and relationship to it.

The consistent use of defined methods of assembly and disassembly pushed weaving to its boundaries and facilitated my comprehension of the different structures and networks of yarns. Experimenting directly with textile production gave me a better understanding of the creative process and the interplay between material construction and final design outcome. Additionally, it provoked my curiosity in relation to textile structures and their three-dimensional capabilities.

In turn, the use of a logical approach, to procure a broader knowledge of textile materiality as a designer, structured my postgraduate research. Ultimately, this inquiry led to an exploration of the depths of knitting in this study.

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3 This quotation was extracted from an article entitled 'Freud, Fabric, Fetish' that was published in the first issue of the academic journal *Textile: The Journal of Cloth and Culture* in 2003. Its author, Ann Hamlyn, was trained as a sculptor and has a doctorate in visual culture.

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ABSTRACT

The research investigates the interactions between the materiality of textiles, body and space through an expanded field in their application for spatial organisation. The exploration of knitting techniques enables the study to examine through material thinking and practice, the possibilities of how textiles can be applied to spatial form making with and without the influence of the body. By defining textiles as stand-alone structures, the research offers through practice, methods regarding the evolution of two-dimensional geometric surfaces and their transference and construction into three-dimensional forms. The practical work explores technical processes in working with textiles and chemicals, flexibility and rigidity that initiate new concepts for form finding. The experimental methodology adopted for the research initiates processes of rethinking how textiles can build new relationships to the human body and its motion. Here, the notion surfaces where textiles can metaphorically be described or accustomed to being 'performers' able to metamorphose through the forces of the body and its movement. The outcome of this study seeks to build relationships between body and movement, textiles and form towards formulating spatial applications for knitted structures. As a result, the research is an experimentation with and without the body, which situates textiles between surfaces and forms.

THE RESEARCH DICTIONARY

Chemical treatment: 'General term for processes in which chemicals other than colorants are applied to textiles' (Tortora & Merkel 1995, p. 110).

Coating: 'Finishing process in which the application of some substance', such as resin or latex, 'coats the fabric on one or both sides' (Tortora & Merkel 1995, p. 123).

Construction: 'Describes the details of structure and quality of a fabric or a yarn' (Tortora & Merkel 1995, p. 133).

Elastomeric: A material that presents elastic properties.

Fabric: 'A flexible sheet material that is assembled of textile fibers and/or yarns that are woven, knitted, braided, netted, felted, plaited or otherwise bonded together to give the material mechanical strength.' (Tortora & Merkel 1995, p. 208)

Fabric construction: 'A general term that includes types of weaves, knits, or other methods of assembly' (Tortora & Merkel 1995, p. 208).

Fabric geometry: 'The three-dimensional structure of a fabric' (Tortora & Merkel 1995, p. 208).

Fabric stretch: 'The ability of a fabric to extend substantially under tension and to recover, rather than remain rigid' (Tortora & Merkel 1995, p. 208).

Flat (single bed) knitting machine: 'A weft knitting machine with needles arranged in straight lines in one or two flat plates called beds. The yarn travels alternately back and forth, and the fabric may be shaped or varied in width, as desired, during the knitting process' (Tortora & Merkel 1995, p. 224).

Fibre: 'The fundamental component that is used in the assembly of textile yarns and fabrics' (Tortora & Merkel 1995, p. 214).

Float: '1. The portion of a yarn in a woven fabric that extends or floats, unbound, over two or more adjacent ends or picks. Warp and/or filling yarns are floated in a prearranged plan to produce the pattern in many fabrics (...) 2. In knitting, that portion of yarn that extends for some length across wales without being looped into the fabric' (Tortora & Merkel 1995, p. 226).

Jersey (single knit): 'A plain knit fabric made on a single set of knitting needles; all the knitted loops are pulled from the face side to the back side of the fabric so the two sides look different' (Tortora & Merkel 1995, p. 309).

Knit: 'General term for process of interlooping yarns either by hand or machine; also the fabrics made by this process' (Tortora & Merkel 1995, p. 309).

Knitting: 'A method of constructing fabric by interlocking series of loops of one or more yarns' (Tortora & Merkel 1995, p. 310).

Spandex: 'A synthetic elastomeric fibre composed largely of polyurethane' (Oxford University Press 2000).

Spatial organisation, in the context of this research refers to the underlying geometrical and spatial appearance of knitted structures. Through the exploration of textile geometries evolving into structures and multidimensional forms, spatial organisation is defined by the three-dimensional relationship between the elements of knitted structures. More specifically, in the way the structural components are spatially arranged and connected to each other.

Structure: 'The arrangement and organization of mutually connected and dependent elements in a system or construct' (The Oxford English Dictionary Online 2000).

Stitch: 'Basic unit of construction in knitted fabric, consisting of the loop of yarn formed by the knitting needle' (Tortora & Merkel 1995, p. 545).

Textile: '1. A broad classification of materials that can be utilized in constructing fabrics, including textile fibers and yarns. 2. Designates the constructed fabric including woven, knitted, and nonwoven structures as well as lace and crocheted goods' (Tortora & Merkel 1995, p. 572).

Texture: 'A term referring to the appearance or hand of a fabric and especially such features as structure, coarseness, openness' (Tortora & Merkel 1995, p. 573).

Vulcanisation: 'A process for making rubber or similar polymers harder and more durable by treatment with sulphur or sulphur compounds (typically accompanied by heat); the hardening or toughening produced by this process' (The Oxford English Dictionary Online 2000).

Weft knit fabric: 'The most common type of knitted fabric, with one continuous yarn running widthwise across the fabric and forming all of the loops in each course' (Tortora & Merkel 1995, p. 626).

Yarn: 'A continuous strand of textile fibers that may be composed of endless filaments or shorter fibers twisted or otherwise held together' (Tortora & Merkel 1995, p. 641).

Yarn count/number: 'A measure of the fineness or linear density of a yarn. May be expressed in indirect units (length per unit of weight or mass) or direct units (weight per unit of length)' (Tortora & Merkel 1995, p. 642).

Yarn geometry: 'The three-dimensional structure of a yarn' (Tortora & Merkel 1995, p. 642).

INTRODUCTION

Context of Research

The Presence of Textiles

Textiles are present 'in every part of our physical environment' (McQuaid 2012, p. 401).[4] Indeed, textiles have played a fundamental part in human daily life for thousands of years. The presence of textiles around the world reveals commonalities between cultures that have no other discernible connections; for example, the similarities in the way people clothe themselves and the manner in which they divide and develop their surroundings. Textiles also form part of an individual's identity, reflect lifestyles and characterise cultures. Whether as an outer covering for the human body or an internal division of architectural domain (i.e. in the form of partitions comprised of curtain walls), textiles are a medium, which exist between people and the space they occupy.

To comprehend the diverse existence of textiles in a spatial context throughout the years, this study considers the work of Gottfried Semper (1803–1879), a German architect and theorist. As Semper (1989, p. 215) states,

> All operations in the textile arts seek to transform raw materials with the appropriate properties into products, whose common features are great pliancy and considerable absolute strength, sometimes serving in threaded and banded forms as bindings and fastenings, sometimes used as pliant surfaces to cover, to hold, to dress, to enclose, and so forth.

In his theory on textile art, Semper (1989, p. 247) defines textiles as the primary art by suggesting that every other forms of art, including

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4 Mathilda McQuaid is the curator and head of the textile department at the Cooper-Hewitt, National Design Museum.

architecture, borrow the origins of their formal language from textiles. The use of textiles as structures and the possible architectural applications of textiles are of particular interest to this study. To fully understand their extensive potential, this research looks at the development of textile manufacturing from manual methods to industrial processes.

Textile and Industrialisation

Designing today is often perceived as an indirect process, forming only when designers use digital tools to interact with their medium; however, the hand-tool relationship is significant in the textile production. Despite mechanical advancements, post-industrial technologies still involve the direct manipulation of raw materials and tools by hand:

> The tools, or the more mechanized tools, our machines, are our guides, too. We learn from them of the interaction of material and its use, how a material can change its character when used in a certain construction and how in turn the construction is affected by the material; how we can support the characteristics of material or suppress them, depending on the form of construction we use. (Albers cited in, Danilowitz 2000, p. 39)5

The fabrication of textiles carries both ancestral knowledge and the potential for research and innovation. The methods of manufacturing have only changed slightly over the centuries. However, the Industrial Revolution (that began in the late 1700s) dramatically affected the field of textiles; increases in speeds and rates of production, transformed textiles into an enormous industry. It also expanded the possibilities of large-scale and technical applications.

Textile Applications, Context and Potentials

As Schillig (2009, p. 80) notes, 'In conventional usage, textile structure relates clearly to the human body, figure and scale'. Textile constructions and applications are often produced at body scale, situated outside the human body

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5 As introduced in the Preface, Anni Albers has had a noticeable influence on the history of textile design. In her 1947 essay, 'Design: anonymous and timeless', she discussed the interaction between designers, materials and tools.

and within enclosed spaces. Research and developments in the area of textile materials has widened the applications of textiles to broader fields in which textile-based building structures have been explored.

Geotextiles is an example of a research based textile application that has been utilised in the field of technical textiles. Geotextiles are defined as a large-scale landscape construction in which the textile structures interconnect and combine with existing lands. In an essay entitled 'A Transformed Architecture', two architects, Philip Beesley and Sean Hanna, describes the development of textile-based technologies that challenges the common belief that textiles and their applications are restricted to body scale. Beesley and Hanna defy misconceptions and communicate the existence of geotextile structures fused with their environment, stating:

> Geotextiles are landscape-engineering technologies that are literally woven into the earth. Applied as a fabric to the surface, they can be integrated into the soil or root systems of vegetation, preserving existing fragile landforms and creating entirely new landscapes. (...) New plantings and their embedded textiles grow together to form a single, integrated structure. (Beesley & Hanna 2005, p. 123)

To fully understand textiles as a technical material for research, it is essential to look at the extent of geotextiles technology and its potential for use in projects of various magnitudes, from small-scale landscapes to entire cities (see Figure 3).

In relation to fabric formed architecture, the use of concrete and textiles is another example that illustrates the union of two distinctly different materials. As Quinn[6] (2006, p. 24) states, 'Just as a corset moulds the body's contours into an hourglass shape, reinforced textile sheaths fabricated with eyelets and laces sculpt wet concrete into curvaceous silhouettes'. This technology combines both the physical solidity of the concrete and the flexibility of the fabric (see Figure 4). It demonstrates a capacity to challenge the perceived materiality of concrete and textiles in form making.

6 Bradley Quinn is a British author and journalist.

Figure 3. Geotextiles, infrastructure application of textiles

Source: K K Enviro Tech Pvt Ltd, 2009 <http://www.florafab.com/index-4.html#>

The study does not aim to duplicate these types of technologies; rather it seeks to illustrate how material combination can shift the materiality of textiles, in particular their flexibility and texture. It is asserted that the manipulation of the properties of textiles could be used to open up new fields of applications.

Figure 4. Canwest Global Theatre Columns (1999). Source: The Centre for Architectural Structures and Technology, 2015 <http://www.umanitoba.ca/cast_building/built_work/can_west_global.html>

Defining the Research

The focus of this study is to investigate and manipulate the materiality of knitted textiles. Materiality is defined as the quality of being composed of matter. It is experienced through the senses: visually, aurally and the tactile. The experience encompasses, but is not limited to, structure, relief, texture and weight.

Using knitted textiles as the base material for analysis, this study explores how form and structure are created and worked with. Given that the main qualities of knitting originate from its construction, an in depth investigation on one specific production method is undertaken; that is, the domestic knitting machine. The numerous techniques employed in the operation of this machine are also examined. The experimentations and the resulting characteristics of the material produced exemplify a range of available possibilities. Using the creative process, the potential of textiles in the third dimension is explored. Specifically, this study addresses the following question: How can knitted structures uncover new qualities of depth and dimension that can be used to reassess awareness and perceptions of their spatial organisation?

The research considers the main properties of knitted textiles. Every stage of the study is catalogued; that is, every sample created is recorded, described and questioned. The project considers knitted textiles not just as surfaces, but also as three-dimensional structures or forms that hold themselves together by means of their own strength and construction. The methodology evolves through the manipulation and transformation of knitted structures into solid three-dimensional forms. It aims to challenges the structural properties of knitting and to broaden the notion of a knitted textile.

‘The textile arts, more than any other, implicate the body as corporeal reality’ (Pajaczkowska 2005, p. 223).[7] In fact, every area of fabrication and application of textiles involve the body as ‘corporeal reality’: a physical material with specific motions. In this study, the physiology of the body, the combination of skeleton, muscle and skin, is significant in form-making developments. Through their flexibility, textiles address the body by following the mechanical movements of the skeleton. Given that textiles communicate the motion of the skeletal system, they relate to the inside of the body. Therefore, this research does not aim at clothing the silhouette, but enveloping and emphasising the physiology of the human body.

A key focus of this study’s methodology is Eadweard Muybridge’s (1830–1904) investigation into the study of motion. Muybridge was an English photographer renowned for his pioneering work in photographic studies of animals’ and later humans’ locomotion. His sequences of images record postures and oscillations of the human body through selected movements that were then used to form a dictionary of actions. The positioning of his research as between science and art led to criticism being levelled at Muybridge’s experiments and the accuracy of his scientific research being questioned:

> The scientific view was that Muybridge’s photographs were inaccurate: Since he used more than one camera, the object was not photographed from a constant perspective or from a single point of view or at equal intervals of time. (Braun 1984, p. 4)[8]

However, Muybridge acknowledged the limitations of his method and described it as a tool for artists to illustrate the human form in motion. As illustrated by ‘Plate 299’ (see Figure 5), Muybridge selected different phases of motion were to convey a sense of movement as a whole. Muybridge’s work responded to science, not in its results, but in the search and methodology used to acquire a better understanding of general perceptions of motion.

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7 Dr Claire Pajaczkowska is Senior Research Tutor at the School of Material, Royal College of Art, London. Her research article entitled ‘On Stuff and Nonsense, The Complexity of Cloth’ was first published in 2005 in *Textile: The Journal of Cloth and Culture.*

8 In her article, ‘Muybridge’s Scientific Fictions’, Marta Braun, a photographic historian, identified details of Muybridge’s study that questioned the scientific accuracy of his work.

Figure 5. Plate 299

Source: Animal Locomotion - Vol. 7 - MALES & FEMALES (draped) & MISCELLANEOUS SUBJECTS, 2015 <http://www.muybridge.org/Other/Animal-Locomotion-Vol-7/15860509_Lkt8W4#!i=1346565799&k=SpXhJBH>

As Williams (1887, p. 358) states, ‘The real discovery which Mr Muybridge made was, therefore the addition of a new method of research, which put before the eye what it could not see unaided’.[9]

Photographs such as ‘Plate 299’ are utilised in this research as methodology tools. By focusing on the structure of motion, the observation of the evolution of forms gives a better understanding of the way bodies and textiles can interact. Looking at the transient phases of motion reveals,

> How the human body moves in the performance of its functions, how backs bends and hips balance and muscles strain and swell. This is not an art but is a mine of facts of nature that no artist can afford to neglect. (‘Animal Locomotion’ 1888, p. 55)[10]

Muybridge’s corpus of photographs shows the individuality of the movement, not only of each species, but also of each animal and each body. Moreover, his explorations generated inquiries on why bodies move the way they do in daily actions. As Mauss (1979, p. 104) states,

> The body is man’s first and most natural instrument. Or more accurately, not to speak of instruments, man’s first and most natural technical object, and at the same time his first technical means, is his body.[11]

Everyday, individuals use their body to interact with their physical environment. This research looks at the attitudes of the human body and examines how these attitudes interact with the structure of textiles. Like an X-Ray, this study looks inside the human body and views the skin and skeleton as being only one material: textiles. Barnett (2012, p. 188) states that: ‘The surface is a liminal space, both inside and out, a space of encounter’.[12] This study is particularly interested in this ‘space of encounter’ and the various actions that textiles engender when in contact with a living body. However, the research does not aim to clothe the body; rather, it focuses on form-making

9 Talcott Williams (1849–1928) was an American journalist and director at the School of Journalism, Columbia University. His article on Muybridge’s work was published in 1887 in *The Century Magazine*.
10 Extract from a review of *Animal Locomotion* in *The Nation*, January 1888.
11 Extract from an essay entitled ‘Body Techniques’ written by Marcel Mauss. Mauss (1872–1950) was a French sociologist and anthropologist.
12 Extract from Pennina Barnett’s essay entitled ‘Folds, Fragments, Surfaces: Towards a Poetics of Cloth’. Barnett first wrote this essay in 1999 for the exhibition catalogue of ‘Textures of memory: the poetics of cloth’. Barnett is a founding editor of *Textile: The Journal of Cloth and Culture*.

processes and the resulting forms that could be implied into textile structures. The work of fashion designers is referred to in this study to ensure that the topic is comprehensively considered; however, the focus of this project is not fashion, but textiles and their construction. In this practical research, the role of textiles as the threshold from body space to public space in the environment is explored and through this exploration, prototypes are developed.

Through an investigation on the characteristics of textile materiality and their applications, this study seeks to challenge textile properties and develop their potential through applied research. An analysis of the literature and relevant documentations is built around three themes: textile, body and space. In Chapter One, a literature review is undertaken to examine these themes and knitting is positioned within the field of research so that its relationship to body and space can be considered.

The second chapter examines how methods and properties define the materiality of textiles and describes the methodology and processes used in this study. This stage of the research illustrates how material experimentations open up new approaches to the application of textiles through re-examining and challenging the characteristics of their geometry, including structure, texture and form.

The creation of solidified textiles challenges their natural flexibility and investigates the spatial organisation of the knit. Expanding the field of investigation, the human body is employed as a topographical entity to create new alternative forms. The third chapter expands the field of textile application through form finding and mapping the physiology of the human body. Reflecting on the body and its surrounding space, this study furthers the exploration and theorisation of a key set of writers and makers by including human geography.

Chapter Four focuses on the exploration of forms through a final manipulation of textiles. A study of the performative potential of knitted structures is undertaken and continued experimentations are conducted on the surfaces formed by human motions. The creation of knitting structures that realise three-dimensional forms through their own tension and solidity, literally and metaphorically, explores the status of textile as architecture for the body. However, it should be noted that the outcome of the research does not aim to be product ready and applied to a spatial project; rather, it functions as a precursor to a space or spatial organisation, a shape or a detail.

The summary of the research reflects on the project outcomes, it connects the investigations on how textile properties may challenge scale and proportion to create spatial topography of performance. The conclusion to the study discusses potential applications and further research within the spatial field of textiles.

Chapter 1: LITERATURE REVIEW

Defining the Field of Research

It has been stated that: ‘Textiles mediate, literally, between the body and architecture—operating somewhere between the fibres of the nerves and the fabric of the city’ (Mitchell 2000, p. 176). This research aims to examine the aspects of textiles as a three-dimensional material and observes the potential of textiles and their status as an art form of spatial organisation. Specifically, this chapter considers examples from practitioners that create forms, spatial concepts and expressions of the physical and metaphorical qualities of textiles. Properties include pliancy, elasticity, expansion, retractability and tactility.

This research and literature review is developed across three themes: textiles, body and space. The practical study applies these themes to position the practice of working with textiles through uniform applications.

Textiles

In relation to materials, Zumthor (2006, p. 25) states,

> Materials react with one another and have their radiance, so that the material composition gives rise to something unique. Material is endless. Take a stone: you can saw it, grind it, drill into it, split it or polish it—it will become a different thing each time. Then take tiny amounts of the same stone, or huge amounts, and it will turn into something else again. Then hold it up to the light— different again. There are a thousand different possibilities in one material alone.

Indeed, textile materials present a ‘thousand possibilities’ (Zumthor 2006, p. 25) from the choice of fibres and structures to the choice of production processes and post-production treatments. Any raw material can be transformed into a yarn, a fabric and an object.

Albers (cited in Danilowitz 2000, p. 33) highlights the versatility of textile materials:

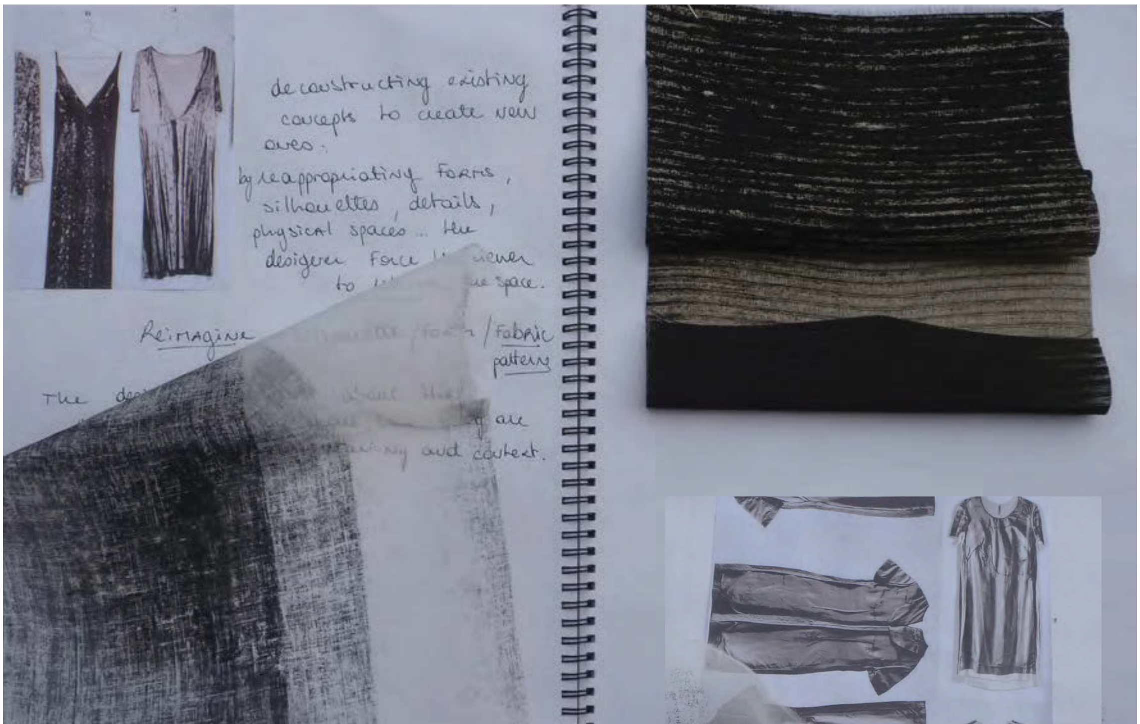
> For just as silk, a soft material by nature, can become stiff in the form of taffeta, through a certain thread construction, and linen, a comparatively stiff material, can be made soft in another, so an endless number of constructional effects can produce new fabrics. The increasing number of new fibers incorporating new qualities creates a special challenge to try the effects of construction on them. Just as chemical treatment has produced fluorescence, so structural treatment can produce, for example, sound-absorption.

To introduce the idea of the potential of textiles, this section presents a selection of work from designers who, in one way or another, pushed the boundaries of their material. One such designer is Swedish creator, Sandra Backlund, who 'develops all her designs from scratch in three dimensions, building them up as a sculptor might construct a work from clay' (Ryan 2012, p. 76). Adopting an experimental approach to the creative process, Backlund's method of designing allows her knitted textiles to create new alternative forms dictated by the material and its interplay with knitting techniques. In relation to Backlund's works, Ryan (2012, p. 84) notes that: 'Either appearing to float in space, rest on flat surfaces, or occupy corners, the works take on the appearance of three-dimensional objects whose exact function is uncertain'. Knitted pieces have the potential to retain their three-dimensional shapes without the presence of a body to support them. In a sculptural way, knitted forms have their own entity.

Others designers (i.e. Martin Margiela, Comme des Garcons, Alexandre Herchcovitch, etc) were explored within the research journals, which reports the processes and methodologies followed throughout the years of study. Extracts from the journals are illustrated in Figure 7, 8, 9 and 10. In these primary research tools, the work of contemporary practitioners is visually associated with samples of experimentations with textiles (see Figure 7 and 10).

Figure 6. A Sandra Backlund Design – Solitaire Knit

Source: Sandra Backlund, 2015 <http://www.sandrabacklund.com/current-collection.php?page=46> Photo credit: Ola Bergengren



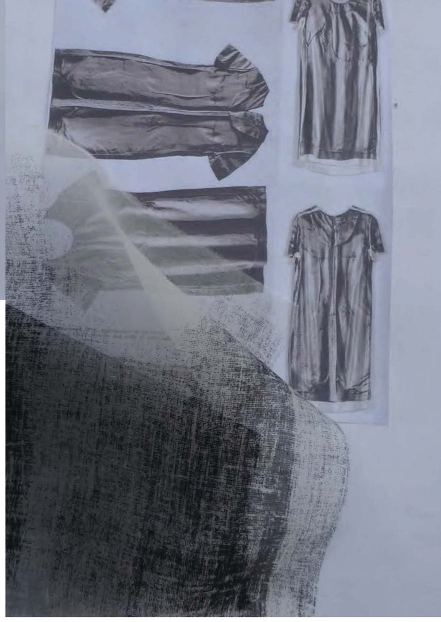


Figure 7. Extract from research journal 1

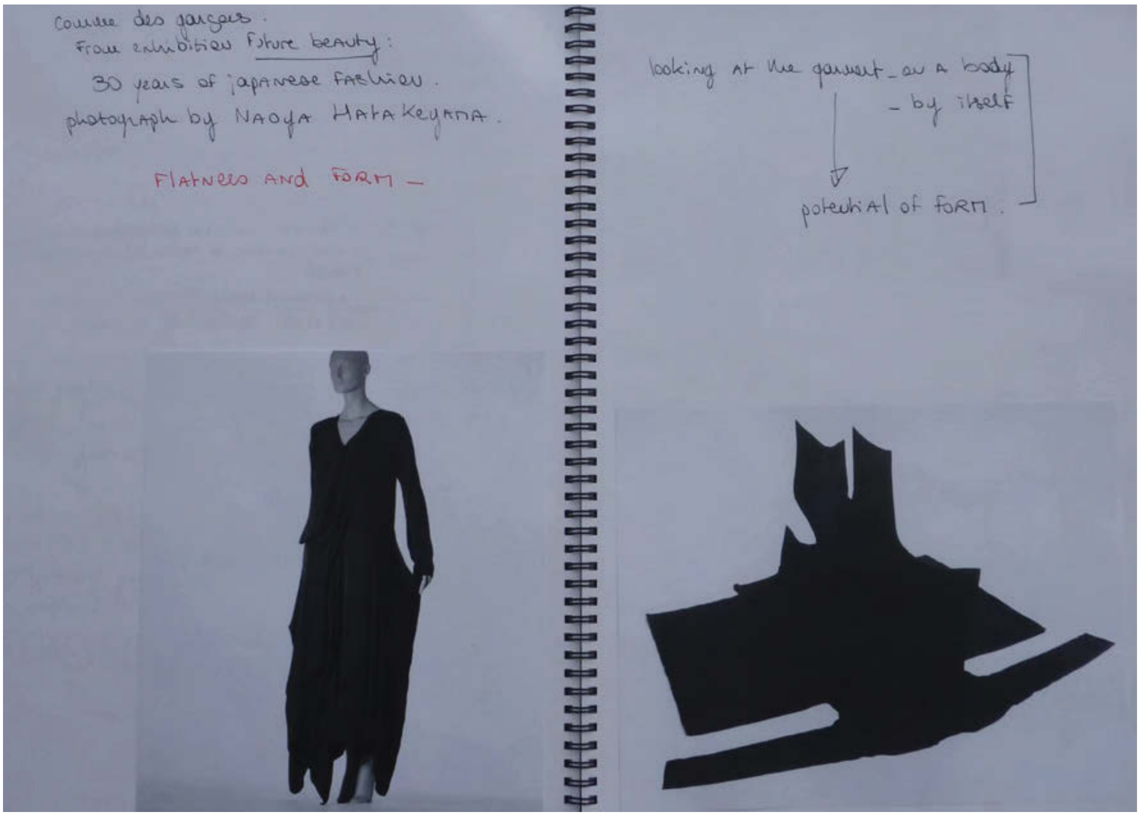


Figure 8. Extract from research journal 2

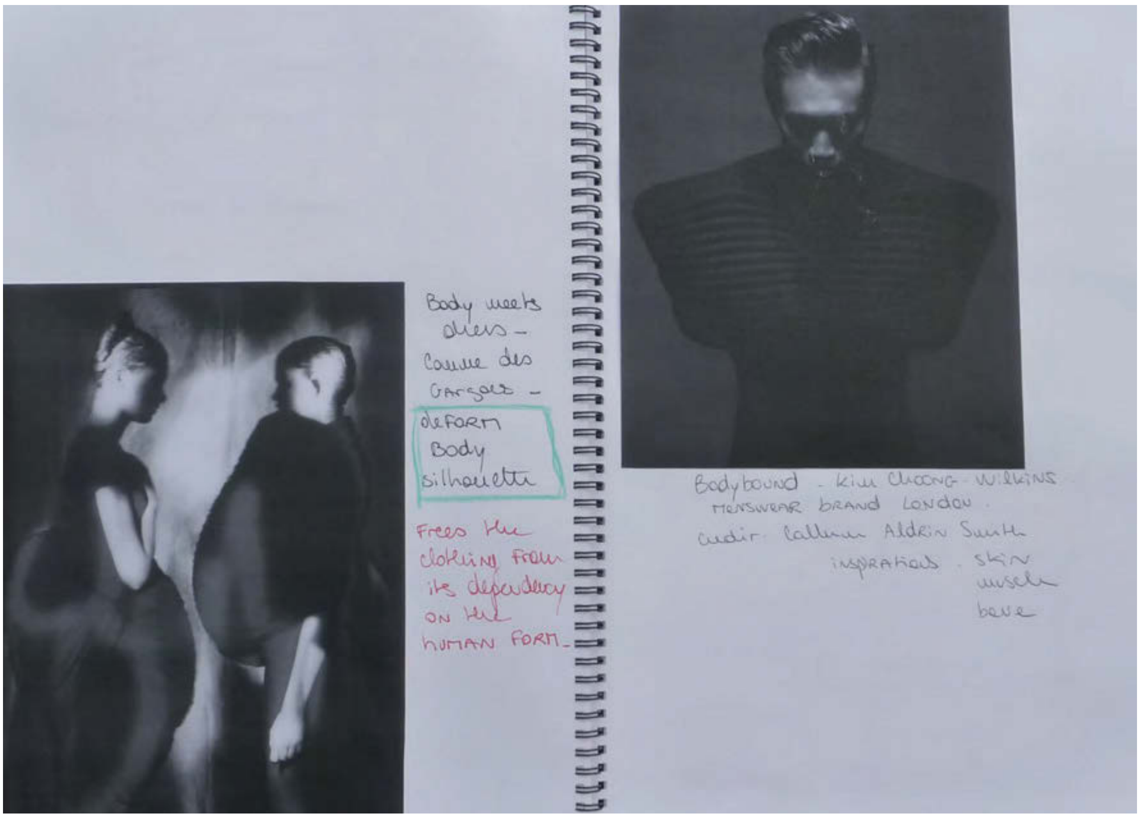


Figure 9. Extract from research journal 3

Figure 10. Extract from research journal 4

Further, this research particularly focused on Japanese fashion designer, Issey Miyake, who pushes the boundaries of materials. Miyake is often referred to as an architect of fabric (Walker 2011), whose experimentations with production processes have led to the creation of alternative designs.

In an essay entitled ‘Wearing a Miyake is like wearing an experience’, Li Edelkoort[13] describes Miyake’s design process: ‘He has chosen the path of transformation and has soaked, washed, crumpled, burned, welded, weathered, eroded, shrunk, twisted and pleated fabrics in order to obtain new dimensions’ (Edelkoort cited in Miyake, I. & Kitamura, M. 2012, p. 18). In the 1980s, Miyake and his design studio conducted research on a variety of areas, such as the choice of fibres for textile construction, to ascertain the best production process for ‘garment pleating’.

Figure 11. Design production processes, ‘garment pleating’

Source: Miyake, I. & Kitamura, M. (eds) 2012, Pleats Please, Taschen, Köln, London.

13 A Dutch trend forecaster.

Figure 12. Design production processes, ‘pleat and crush’ step 1

Source: Miyake, I. & Kitamura, M. (eds) 2012, Pleats Please, Taschen, Köln, London.

Figure 13. Design production processes, 'pleat and crush' step 2

Source: Miyake, I. & Kitamura, M. (eds) 2012, Pleats Please, Taschen, Köln, London.

A pleat must be distinguished from a fold; a pleat 'is a fold, but it is also an edge of another kind' (Quinn 2003, p. 218). Pleats are considered as fabricated folds, they represent folds dictated by their production process. While folds can be described as free, pleats are fixed; 'sealed by heat into the very heart of a textile's fiber, the form becomes permanent' (Schilling cited in Miyake, I. & Kitamura, M. 2012, p. 186). However, despite being permanent, pleats have the potential of transformation through motion. Indeed, pleats are described as,

> An architecture of becoming that is searching for a multiplicity of variations and possibilities while maintaining continuity. A work where material and process collide, overlap and melt like strata of a new and surprising tactility. Where form and detail are only the by-product of the folding into one another, of shapes answering other shapes, of forms echoing other forms. (Edelkoort cited in Miyake, I. & Kitamura, M. 2012, p. 21)

Another contemporary practitioner of particular interest in this research is Orly Genger, an American sculptor. Her sculptures are made of hand-knotted nautical rope, which are layered on top of each other to create three-dimensional forms. A particular interplay occurs during the installation of these sculptures (see Figure 14). As Genger expresses, the physical process of building the work can be though as a form of 'wrestling' with the material. This intimate relationship generated through the creation of the sculptures is significant for this research and the use of the body motion in form making.

The second section of this chapter addresses the 'architecture of becoming' when the human body is in motion and interacts with textiles in its surroundings.

Body

Considering textiles and the body, Pajaczkowska (2005, p. 242) states,

> As cloth in clothing is the most tactile of surfaces, always in contact with skin and body it carries the contradictory meanings of being an external surface turned outward towards the gaze of the viewer, while remaining forever proximate.

Figure 14. Exploring form-making processes

Source: 2016, <http://www.madisonsquarepark.org/art/behind-the-scenes-installing-orly-gengers-red-yellow-and-blue>

Figure 15. Building sculptures, Orly Genger, New York 2013

Source: 2016, <http://www.madisonsquarepark.org/art/behind-the-scenes-installing-orly-gengers-red-yellow-and-blue>

This statement sets the context for the research in relation to the proximate relationship between bodies and textiles. The conception of textiles as an envelope that forms a relationship with the human body is an important element of this study. The notion of wrapping the body and enclosing the space around it has been considered in examinations of Miyake's work; for example, The Pleats Please project, 'investigated and explored the nature of pleats and their implications for enveloping, collapsing and revealing the body in movement' (Edelkoort cited in Miyake, I. & Kitamura, M. 2012, p. 26). Conceptualising textiles as having an aim of constructing an envelope for the body and as a form of architecture leads to questions in relation to how textiles in three-dimensional forms have the potential to reorganise the human form. The interplay created between the human silhouette, motion and form is an important element in this research.

The perception of the body being enveloped in textiles is particularly interesting. Miyake's design process 'explores the fundamental relationship between the body, the cloth that covers it, and the space and room that is created between these elements' (Miyake Design Studio 2014, para. 6). Bonnie English explains this phenomenon in her book entitled 'Japanese Fashion Designers: The Work and Influence of Issey Miyake, Yohji Yamamoto and Rei Kawakubo' (2011, p. 21) when she states that, 'it is this central concept of space between the body and the cloth, called ma in Japanese, which creates a natural freedom, and general flexibility in the garment'.

Ma as an aesthetic concept is defined as a way of conceiving space and time; 'The word ma basically means 'interval' between two (or more) spatial or temporal things and events' (Pilgrim 1995, p. 56). This study views ma as the spatial interval between two material things. It is variable, not permanent. The meaning of the concept of ma can be explored by the interaction between people and their environment; it is the interval between; the space between; the gap between. This research aims to explore this notion of ma by focusing on the body and how it experiences ma generated through the use of textiles.

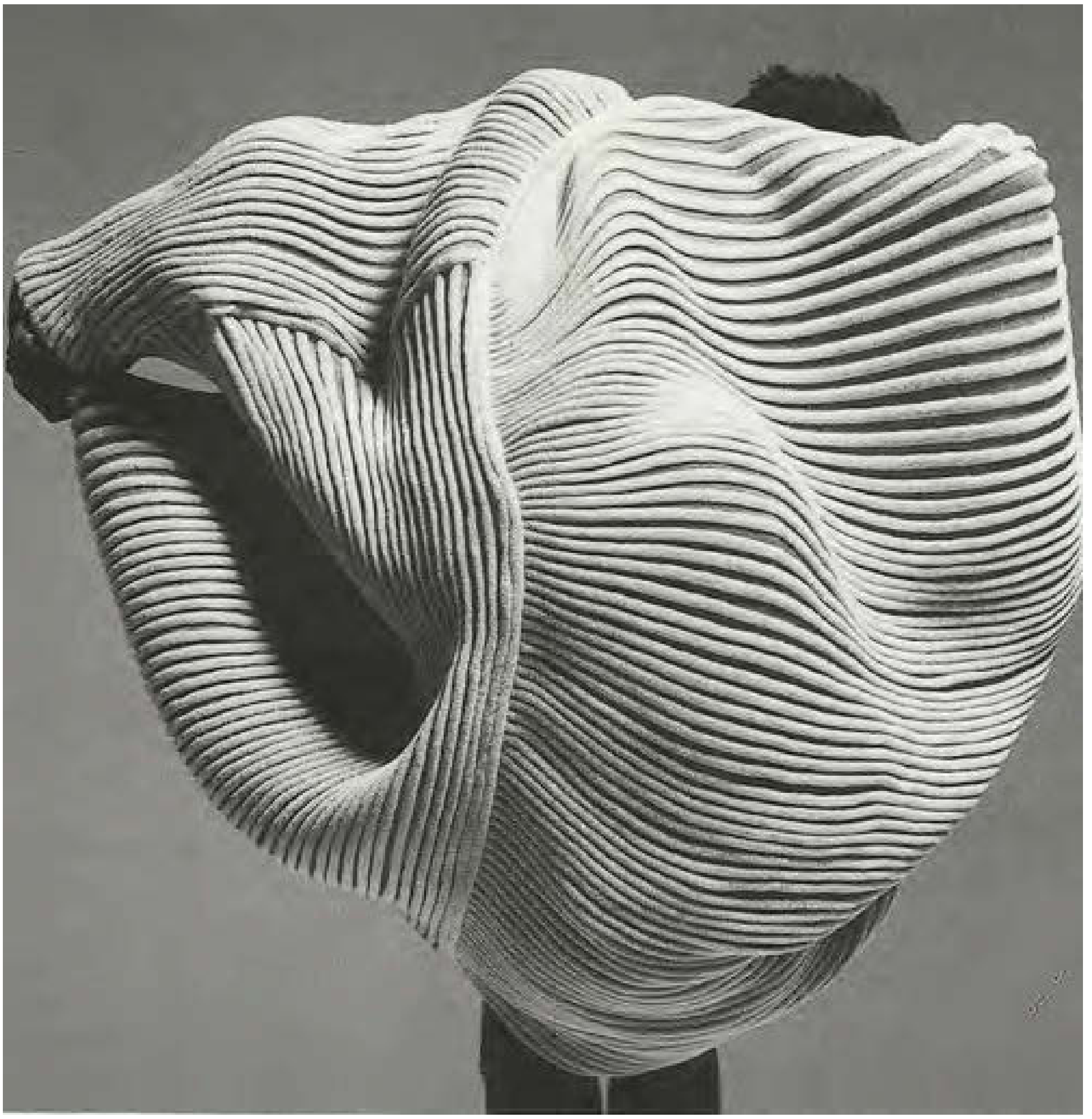


Figure 16. An Issey Miyake Design Spring/Summer 1885

Source: Pinterest, 2015 <https://www.pinterest.com/pin/262194009532941032/>

Gabi Schillig is a German architect whose practical work focuses on the field of body space. The field of body space is defined as the exploration of the relationship between the body and its surrounding space. In considering the way in which bodies and urban spaces condition each other and interact, Schillig's created 'Public Receptors' and states (2009, p. 56),

> The proposed temporary textile structure, which can be worn, is a hybrid: functionally it is a third skin, which encompasses a new type of space, but in a structural sense it is categorized in the broadest sense as clothing.

Schillig used tactile body structures to form textile objects composed of woollen felt. The objects produced present characteristics to be metamorphosed from flat constructions to three-dimensional modules. A photo-documented performance in New York City illustrates dancers interacting with these movable structures (see Figure 17). The 'soft geometries' were grafted into architectural elements of the city such as staircases or gates. The dancers' bodies and their performances occupied the textile structures and the body's motions were used as an active part of the design process. Body performance and geometric forms were combined to create an open spatial system that generated a dialogue between dancers and their environment.

Figure 17. Schillig's textile objects 'Public Receptors'

Source: Gabi Schillig, 2009 <http://www.gabischillig.de/works/Public+Receptors>

Figure 18. Hélio Oiticica's Parangolés

Source: Marco Silva, 2015 <http://www.saladeaulainterativa.pro.br/texto_0004.htm>, E-flux, 2006 <http://www.e-flux.com/announcements/helio-oiticica-the-body-of-color-2/>, Irish Museum of Modern Art, 2014 <http://www.imma.ie/en/page_236815.htm>

The Brazilian Neo-Concrete movement[14] influenced Schillig's work, particularly Hélio Oiticica's work 'Parangolés' (see Figure 18) that asserted that 'complex textures can only be revealed through the gestures and movements of the person who wears it' (Dezeuze 2004, p. 59). The 'Parangolés' (i.e. an invitation to be worn) trigger viewers to take part in the performative process and 'to move around or inside a work to observe its structure and formal qualities' (Dezeuze 2004, p. 62). The intimate process of encountering the material creates a sensory relationship; the material is discovered as a whole through its features, including its structure, texture, form and boundaries.

A significant notion emerges from Schillig's and Oiticica's work; that is, the potential for tactile qualities of space. A tactile quality of space is a concept that Zumthor (2006) develops in his book 'Atmospheres: Architectural Environments, Surrounding Objects' in which he presents arguments on the topic of sensory perception in the field of architecture. Specifically, he considers the sensory experience of architectural materials. A direct comparison can be drawn between the sensory experience of architectural materials and textile materials.

Space

As Pallasmaa (2012, p. 44) states, 'Our bodies and movements are in constant interaction with the environment; the world and the self inform and redefine each other constantly'. Thus, human beings are constantly transforming their surroundings, shaping and 'producing' spaces. In his book, 'The Production of Space', Henri Lefebvre (1991) defines 'production' as 'reappropriation rather than creation'. He wrote (1991, pp. 169–70):

> Can the body, with its capacity for action, and its various energies, be said to create space? Assuredly, but not in the sense that occupation might be said to "manufacture" spatiality; rather, there is an immediate relationship

14 The Neo-Concrete movement (1959-61) investigated the notion of body performance, focusing on spectator's perception and their spatial relationship with art.

> between the body and its space, between the body's deployment in space and its occupation of space.

In a reflection on body and space, this section reviews the use of textiles in architectural scales through the work of Petra Blaisse. A Dutch artist and designer, Blaisse, founded 'Inside Outside', a design studio in Amsterdam. The studio focuses on the utilisation of textiles and light for interior spaces and reconfiguring landscapes for exteriors spaces. Blaisse employs textiles in a manner that goes beyond their traditional applications. Tim Ronalds (cited in Blaisse & Kayoko 2007, p. 102) describes his encounter with the potential of curtains in architectural design after collaborating with the Inside Outside studio: 'the curtains make a primal connection between space and people: the stuff that wraps our bodies and touches our skin becomes an element of architecture (...) the curtains—makes for performance'. Textiles introduce a sense of movement to the permanence of architecture; this malleability implies interaction with the human body. Comparing her work to fashion, Blaisse (cited in Weinthal 2008, p. 67) describes:

> We do not drape the cloth around another shape: we let it hang down from a certain structure or form; it falls down, sways, moves sideways. Curtain and body touch each other only when the curtain is pulled, pushed, lifted, moulded, rolled, stored, felt or stroked.

As an envelop for the body's silhouette and a covering for walls or thresholds, textiles have a definite spatial presence. As Eastop (2012, p. 10) states, 'Textiles shape space in many ways: as covering to protect against the weather or to uphold ideas of modesty; by providing thermal or acoustic insulation; and as decoration'. Textiles can enfold, hold, contain and present many potential implications for spatial organisation. These potential implications are investigated in Chapter Two through an exploration of the materiality of knitted textiles.

Chapter 2: PROPERTIES AND METHODOLOGIES

Textile Properties

The materiality of textiles refers to the nature and properties of a material and includes the sensory experiences of users in relation to a textile's tactile, visual and other physical traits. This study specifically analyses the properties of textiles produced using a domestic knitting machine. As Brown[15](2005, p. 36) states,

> The qualities of textiles are dependent on the interaction between their material properties and their structural geometry, or on the fibers and the way in which those fibers are ordered. Each of the textile techniques represents a very specific architecture of fibers which can be used to create a wide variety of materials for design.

Thus, the characteristics of textile are determined by their fabrication, flexibility, form and pattern design result from a combination of fibre properties and the network that organises their assembly. The parameters set during the production process define the final textile materiality. Each stitch, which reflects a combination of parameters, embodies a specific network of fibres.

The definition of textiles as flexible materials formed by the structured organisation of natural or artificial fibres is significant to this research. While a piece of cloth can define a finished piece of textiles, a piece of knitted cloth can also be viewed as raw material. Thus, a piece of knitted cloth can go through a post-knitting process and be moulded into a final shape or object. A peculiarity of textile fabrication is that the final stage of formation can also be included earlier in the process; indeed, it can be included at the initial construction of the textile. The process of making a textile can define the

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15 Susan Brown is assistant curator at the Cooper-Hewitt National Design museum, New York.

shape of the final object and give a three-dimensional form to the structure. This ability to alter the production process to achieve desired formal outcomes is of particular interest to this research and is further investigated through the prototypes.

Research Focus

This study focuses on the properties of materials and experiments with the capabilities and production processes of these materials. To push the applications of textiles to their furthest boundaries, the methodology adopted in this study concentrates on shifting important physical properties of materials such as flexibility and texture. Specifically, the evolution of two-dimensional geometric surface patterns and their transference to three-dimensional form are investigated. Emphasis is placed on the technical aspect of knitting construction where knitting is understood to be the configuration and interlocking of yarns. The methodology (discussed in more detail later in this chapter) follows the production processes to explore how knitted structures can be used to uncover new qualities of depth and dimension that make us rethink our awareness and perception of their spatial organisation.

Flexibility

The construction of textiles determines their characteristics such as their ability to alter shape (i.e. deform, bend and twist) to consequently fit the human form or any other form. The construction and experimentation of knitted structures can be used to extend their boundaries for use in alternate applications. This study explores the ability of knitting to retain its elastomeric memory and experiments with the material as a system of capabilities to activate the ‘push’ and ‘pull’ of the materiality.

By looking at the different structures inherent in knitted textiles, this inquiry also aims to investigate the spatial geometry of fabric construction by questioning the relationship between materials and their resulting forms. The objective of this study is to observe and push the boundaries of textiles through the ranges of their structural flexibility. Such material experimentations should reveal new approaches for the applications of knitted textiles by re-examining and challenging their characteristics.

Texture and Touch

As stated earlier in this chapter, the texture of textiles refers to the fibres and structure that organise their assembly. A key step in this study's methodology is the investigation and descriptions of perceptions of texture of the samples created. Mitchell (2012, p. 11)[16] notes that:

> Textiles (...) articulate subtle physical sensations between substance and surface, and are most closely known to us through their relationship to the skin and to the sense of touch, a sense which is actively encountered through the making of textiles by hand.

Working with textiles enables the maker to explore the importance of the sense of touch; interactions between the hand and the material occur at every stage of the making process from handling the raw material to examining the final product. Texture and touch in the textile field are as important as visual aesthetics. The interplay between a textile maker and its material is very intimate; a textile maker must approach a material by responding to its characteristics, handling it and pushing the boundaries of its properties. Users engage with textiles at a similarly sensorial level,

> The particular role that textile plays in mediating between the body and the built environment —the way that textile as skin or membrane provides on the one hand a very real, tangible point of contact and material boundary and on the other hand a more ambiguous metaphorical boundary between self and "not self"—and also of course, what is crucial to this relationship, the importance of tactility and continuity of touch. (Bristow 2012, pp. 45–6)

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16 Victoria Mitchell is a senior lecturer at the Norwich University College of the Arts. She is also the book reviews' editor for *Textile: The Journal of Cloth and Culture* and the editor of *Craft Reader*. Her essay entitled 'Textiles, Text and Techne' was first written for the 1997 conference 'Obscure objects of desire: reviewing the crafts in the twentieth century'.

Encountering material in daily living allows repetition to create a habit. Starting with visual and followed by tactile sensations, experiences with textures form the basis for attitudes users may have towards a textile. Touch is learnt in combination with visual experience; therefore, users often expect a material to posses certain qualities on first viewing. Additionally, the sensations that emerge while interacting with a textile (e.g. sensations of weight) are also considered in this study. Touch sensation can be formed via hand manipulation, but the touch of a fabric is also inseparable to how it feels on the body.

A kinaesthetic experience represents another level of interplay with material related to movement. Kinaesthetic (also called muscle sense) refers to 'the sensation by which bodily position, weight, muscle tension, and movement are perceived' (Collins Dictionary 2015). This concept is primordial in this research and its connection with Muybridge's study of body motion assisted in designing the methodology.

In light of these observations on touch and texture, the methodology adopted in this study plays with yarn combinations and uses chemical additives to manipulate textile textures during the production processes. Physical properties are shifted to introduce the future user to contrasted tactile experiences, which aims at raising awareness on the perception of textiles.

Research Methodology

Textiles involve dualities and the methodology of this study worked around them in selecting raw materials for research. A primary framework was developed through the exploration of dualities, such as hard and soft, stiff and flexible, small and large, inside and outside. Three types of raw materials were employed in this study:

1. Yarns made out of fibres that present new properties when assembled into a structure.
2. Knitted flat structures that form geometries and can be used in the process of three-dimension form making.
3. Chemical additives applied to textiles to challenge their characteristics.

Each sample created is recorded in the research catalogue. A systematic description and analysis of the outcomes was undertaken to develop a form-finding processes in relation to the research purpose.

Yarn

Yarn is the fibre that is collected into a strand and then twisted for greater compactness and strength before being knitted into a structured network. The selection of yarn was an important stage for this research, as the yarn used can dictate some of a textile's final characteristics. Yarn terminologies and vocabulary related to touch are defined below.

The study selected yarns for their physical properties (i.e. length, fineness, crimp, softness, toughness, resiliency, density and flexibility) and mechanical properties (i.e. strength, elasticity, extensibility and rigidity). The different fibres utilised in this project can be divided into two categories: natural and synthetic fibres. The following natural fibres were selected: cotton, linen and merino wool. Notably, cotton fibres have a tenacity and inelasticity that make them wrinkle and crease easily; linen fibres are stronger than cotton and wool fibres and while they wrinkle easily, do not have elasticity. Merino wool fibres are softer than cotton and linen, maintain their shape when stretched, and are tenacious and wrinkle resistant. The combination of cotton and linen with other fibres, such as merino wool or Lycra, can redirect their properties (i.e. alter their minimal elasticity). In fact, synthetic fibres such as Lycra have been chosen for this study. Lycra or spandex is a fibre with major elastic properties. It is lightweight and soft with good strength and durability. Its ability to be stretched repetitively and to recover to its original shape makes it a major asset to research exploring the flexibility of textile structures. The second type of synthetic fibre utilised in this research is nylon monofilament, which presents high strength, resilience as well as great flexibility.

Several methods exist to combine fibres and challenge their physical properties; each method produces different materiality effects. First, fibres can be combined during the spinning process to form a single yarn. This type of yarn was utilised in this study: a Colcolastic cotton/Lycra yarn that combined the strength of the cotton with the elasticity of the Lycra. Second, multiple yarns can be knitted together as an entity. Third, and the main method employed in this project, involved the alternate utilisation of multiple yarns during the construction of the knit.

While not a primary element of this study, different colours were used to accentuate the geometries of the knitted structures. Specifically, black, grey, white and red yarns were combined to reveal the geometric rules and principles applied to the knitted structures.

Interlocking Yarns and Knitting Geometries

As Emery[17] (1994, p. 40) wrote:

> Knitting in its simplest form consists of successive rows of 'running' open loops, each loop engaging the corresponding one in the previous row and being in turn engaged by the corresponding one in the following row.

There are two main kinds of knitting methods: hand knitting and machine knitting, which includes domestic and industrial machines. All techniques feature their own individual characteristics and can produce different results. A hand-operated single bed flat knitting machine[18] (also known as a domestic knitting machine) was used in this study. The automated functions of the domestic machine were explored to create a diversity of effects and patterns including two and three dimensionality (see Appendix for details on how to operate the machine).

The fabrication of textiles involves direct contact with the tools and materials and generates a peculiar relationship between the hands of the maker, the knitting machine and the knitted product. The repetitive and gradual process that comes from operating the machine by hand is an essential stage in the experimental methodology of this research. As the body motion is required to operate the machine, the body engages with textiles during construction, which leads the research in the exploration of structure and form.

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17 Irene Emery (1900–1981) was curator of technical studies at the Textile Museum in Washington.
18 More specifically a 4.5mm standard gauge knitting machine is used in this research. The gauge refers to the fineness size of the knitting machine: the needles are situated 4.5mm apart.

Figure 19. Domestic knitting machine

Source: Knitwear maker, 2015 <http://www.sehkelly.com/makers/hand-loomed-knit-wear-maker-south-west/>

The methodology adopted in this study uses a set of knitting techniques as operational tools for further three-dimensional experimentations in form making. A knitted textile is formed with interconnected loops of yarn, creating geometries specific to each interlocking pattern. The first stage of the research investigates knitting stitches. Each stitch structure interconnects yarns and can create three-dimensional effects, within the surface texture, which are fundamental characteristics of a textile.

Knitted fabrics are composed of rows of loops with each row caught into the row previously formed. It is the ability of these loops to stretch when pulled by a stress that enables knitted textiles to adapt to the changing shape of a moving body. As Brown (2005, pp. 46–8) describes, ‘knitting is a looping technique, and the knit stitch can be easily distended in either direction’. The adaptability of knitted textiles is a major characteristic of the material; their flexibility is determined and inherent in the knitting process.

Knitting machines have two basic forms of construction:

1. Weft knitting in which yarns primarily travel in a horizontal direction, across the width of the textiles.
2. Warp knitting in which the loops are formed following a vertical direction along the length of the fabric and that, visually, creates zigzags.

Each type of construction has many variants; however, weft knitting is the focus of this research. Weft knitting[19], in the context of the single bed flat knitting machine, permits the production of numerous surface textures, depending on the yarn and type of stitch. Variations of protocols within the fabrication process will produce materials with different qualities and features.

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19 Weft knitting can also be divided in three categories of stitches. Firstly, rib stitches, which alternatively combine knit and purl stitches. Secondly, purl, which are formed of purl stitches only. However, these two categories cannot be knitted on a single bed flat knitting machine. At last, the stitches explored in this research, single jersey, which are made of knit (face of the fabric) and purl stitches (back of the fabric).

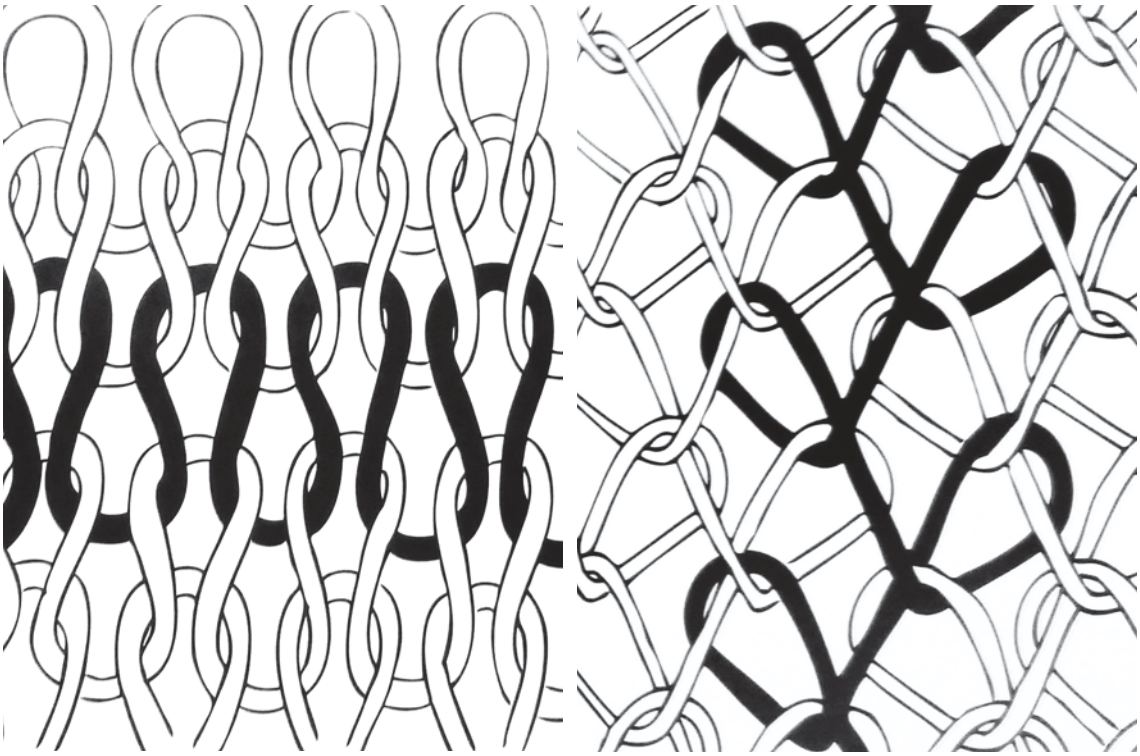


Figure 20. Weft Geometries (left) in comparison to Warp Geometries (right)

Source: Sissons, J. 2010, Knitwear, AVA Academia; Distributed in the USA & Canada by Ingram Publisher Services, Lausanne, La Vergne, TN.

A thorough investigation on single jersey and automated stitches (i.e. slip stitch, weaving, etc.) was undertaken to develop a comprehensive knowledge of how the surfaces of textiles could be interpreted as spatial organisation. A photographic study of the underlying geometrical and structural principles of these knitting techniques has been included in the related research technical file. Specifically, this study:

1. Observed geometric rules and principles; and
2. Considered the development of material spatial characteristics.

Pre-punched pattern cards are utilised on the knitting machine to control the sequence of operations and create two and three-dimensional patterns. They indicate a dot-matrix programme that commands the machine on how and when to knit, tuck or slip a stitch. Punch cards can metaphorically be described as a portal that translates geometry into materiality. Their utilisation questions the relationship between the matrix geometry, the construction of the textile and its final spatial organisation.

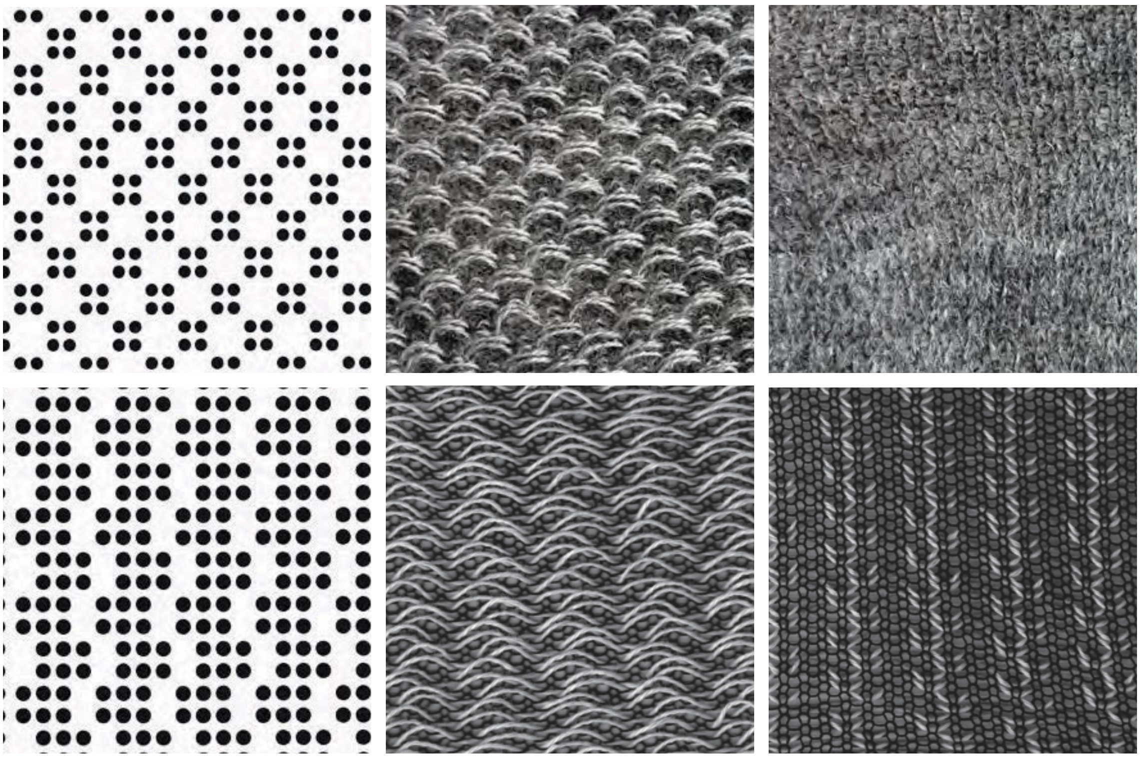


Figure 21. Geometries of punch cards and their transference into materiality

Beesley and Hanna (2005, p.109) investigated behaviours of textile-interconnected systems and compared textile construction to the engineering of building, stating:

> Every fiber has an integral role in maintaining structure, each as important as its neighbor. The fibers are long, usually spanning the entire length or width of the textile. The structural properties are evenly distributed through the fabric, as each thread connects to the others. Instead of fixed, rigid connections based on compression, textile structures use tension. The binding of one fibers to the next is achieved through the tension exerted by the immediately adjacent fibers. Rather than relying on support from the previous, stronger member, the system is circular, holding itself in balance.

Thus, it is evident that a comprehension of the structure, as a whole, is essential in working with textile material. A yarns connections and tension within the system are fundamental to the textile and will define its physical and mechanical capabilities.

An examination of geometric basis structures in early stage experiments created components for later form-making developments. As previously stated, the creation of three-dimensional forms within an interconnected system of yarns is influenced by various parameters and elements. The research sought to obtain a multidimensional understanding of textile structure. To achieve this, a photography study (see technical file) was undertaken to bring out details of structure and reveal features of the knitted textiles.

Properties of Textiles and Additives

The investigation focuses on geometric organisation and textile materiality to discover how to materialise the geometries of knitting structures. Experimentations in geometry and textiles investigate the network of yarn within two-dimensional forms. However, the study aims to push the techniques of knitting further by solidifying textile structures into a third dimension. Post-knitting chemical treatments are applied in order to transform tactile and structural characteristics implicit in knitted textile fabrications. Experimental approaches resulting from habitual interactions between hand and material (i.e. pulling, stretching, crumbling and twisting) are used to manipulate textile surfaces. This inquiry from flexible to inflexible is conducted through two chemical applications, resin and latex.

Glass Coat is a two-component epoxy resin system that forms a thick synthetic substance that solidifies into transparent solids. The resin is made with an epoxy hardener ‘part A’ and an epoxy resin ‘part B’. A list of the different chemicals constituting each component and their proportions is set out below.

Epoxy hardener part A:

- 30–60% of Isophoronediamine;
- 30–40% of Benzyl Alcohol;
- 10–30% Bisphenol A Epoxy Resin.

Epoxy resin part B:

- Over 60% of Bisphenol A Epoxy Resin;
- 10–20% of Cresylglycidylether;
- Traces of Epichlorohydrin.

The fluid structures inherent in textiles are re-configured through the application of resin, which generates newly formulated dimensions. The creation of solid forms produces new geometries within the structure of the knit.

Spray Latex, a natural liquid material, is a moulding compound based on pre-vulcanised natural rubber latex. Latex properties include elongation and memory form without permanent distortion and only require drying to be activated. The use of this chemical in coating permits the elastomeric characteristics of knitted textiles to be accentuated. While the material created moves as a whole complete surface, the geometry of the knit is fixed and captured within the latex.

Chemical additives shift the texture and shape of knits; they construct and deconstruct texture and form. A three-dimensional approach is added to the knitting experiments with a focus on structural geometry, texture and form. The chemical manipulations establish different reactions and outcomes peculiar to each chemical (for records of the outcomes see the technical file for each sample).

Technical File: Exploring Material Manipulations and Transformations

The technical file should be viewed as a living methodological resource. It contains a systematic description of the methodologies used and record all the knitted samples created in this study. Additionally, it is employed as a tool to isolate and demonstrate the specific structures and geometries of the materials. Thus, it assists the study in its purpose; that is, to reconsider our awareness and perceptions of textiles through their spatial organisation.

Prototype No. 1

The practice-based research firstly explores and questions the flexibility of knitted structures with a single knit stitch (see Figure 22). The textile is constructed with a set of needles, which pull every loop in the same direction. Consequently, the images in Figure 16 reveal that the two sides of the fabric look different. The knitted surface can be considered as a final piece; however, to push the inquiry further, it has been coated with resin. By dipping the piece in resin, the wool's materiality was affected both visually and through its tactile qualities. An instinctive manipulation of the material informs the first step of this study's methodology. The model is created by rotations of the sample by hand. Previously flexible, the network of yarns is later captured by the hardness of the resin. The creation of a solid structure and the association of two contradictory materials (i.e. resin and wool) reveal the ability of the textile to generate alternative forms.

Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	4 / 120 / 280
Yarn	wool
Additive	Resin

Figure 22. Prototype No. 1[20]

20 *Stitch Dial* refers to the size of the stitch, see Appendix page 121 for more informations.
Width indicates the number of needles utilised and *Length* indicates the number of rows knitted.

Prototype No. 2

The research further explores knitting geometries using a punch card and slip stich. The slip stitch is produced when one or more needles are placed on hold while a row is knitted. The inactive needles lead the yarn to form a horizontal line below the needle on one side of the knit. However, in this experiment, only a single colour of yarn was employed making the geometry of the knit difficult to investigate. Accordingly, the next experiment considers the use of two distinct colours of yarns.

The analysis of Prototype 2 is also subject to hand manipulation; specifically the prototype is partially twisted. The cotton yarns lose their flexible and soft properties once resin is applied to the whole surface of the knit. The chemical additive shapes the textile structure and moulds it into place, lessening the flexibility of the knitted form. The result is a solid prototype (see Figure 23) that is sculpted into an abstract form.

Knitting pattern	Slip Stitch
Punch card number	14.A
Stitch Dial/Width/Length	3 / 120 / 265
Yarn	Cotton
Additive	Resin

Figure 23. Prototype No. 2

Prototype No. 3

Two contrastingly coloured wool yarns are utilised to build a punch lace stitch. The first yarn knits all stitches, while the second knits stitches in correspondence to the holes on the punch card matrix. The combination of the wool's physical properties (including natural elasticity, resistance and softness) and the punch lace stitch defines the shape of the piece. It also influences the resulting structure's tactile characteristics. Figure 24 illustrates the interplay between the matrix of the chosen punch card and the network of yarns produced; it explores the geometry of the punch lace pattern and its transference into textile materiality. The piece is also partially plunged in resin and compressed by hand. The result produces a textile, which associates opposing properties; the texture is both soft and hard and the structure, both elastic and solid. The use of resin challenges the visual and tactile experience of the knit materiality.

Knitting pattern	Punch lace
Punch card number	2.A
Stitch Dial/Width/Length	6 / 120 / 150
Yarn	wool
Additive	Resin

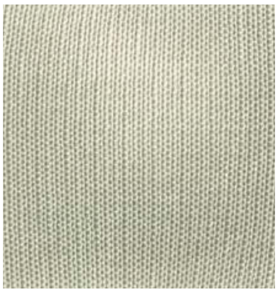
Figure 24. Prototype No. 3

Prototype No. 4

The study then returns to the single knit stitch to explore floats in the textile construction. The process consists of releasing stitches within the width of the knit. Emery (1994, p. 40) describes the process as follows,

> The alignment of loops and their interconnection is vertical; and if one loop is released, the previous loops in the same vertical 'wale' will be released one after the other, although none in the same horizontal row will be affected.

The resulting system combines tight and loose structures and visually creates a landscape of yarns. Resin is applied to the entirety of the knit, transforming the model into a tectonic terrain. The formation of a solidified form reveals the potential for spatial organisation in a structure. The interplay of materiality includes notions of soft/hard, flexible/rigid, which displays visual and physical contradictions.

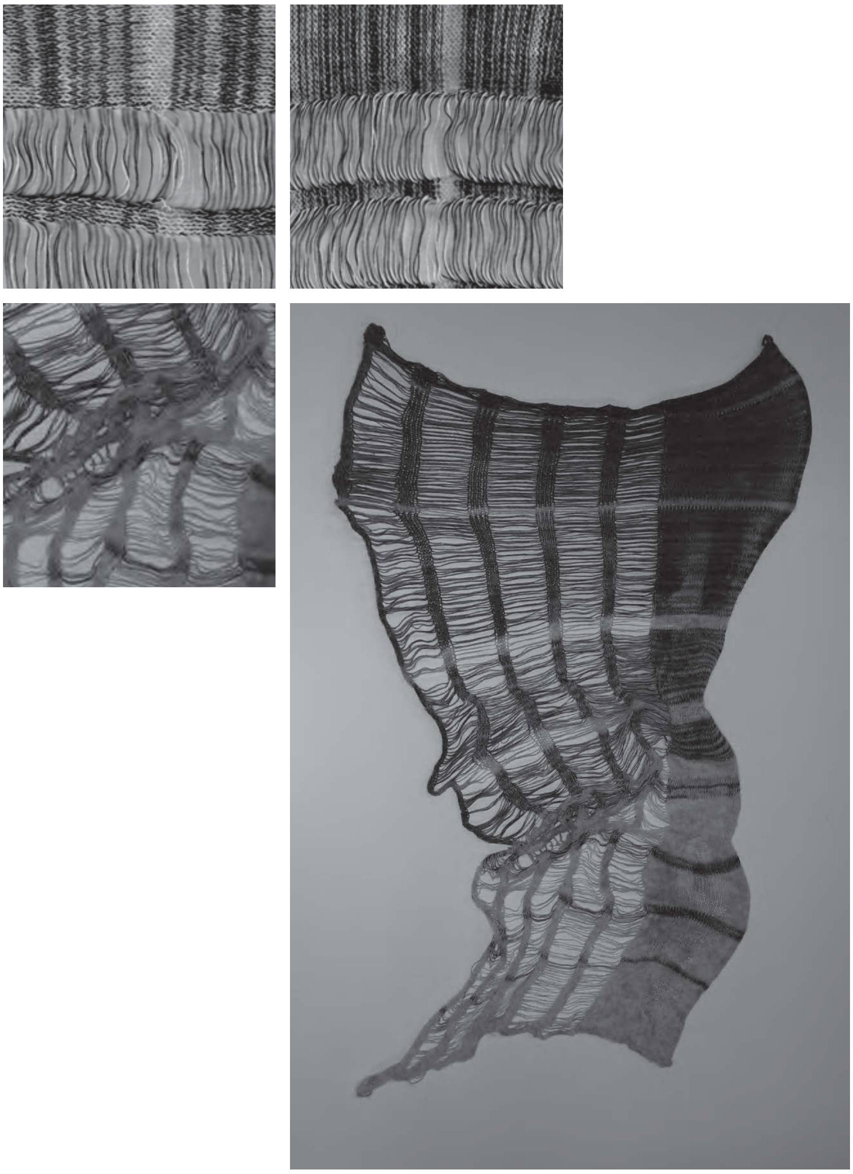



Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	4 / 120 / 240
Yarn	wool
Additive	Resin

Figure 25. Prototype No. 4

Prototype No. 5

Elaborating on the previous experiment with floats, a new experiment is undertaken that utilises a structural organisation formed by loose and tight networks of stitches. On a technical level, this is achieved by creating floats within the structure; this introduced multiple densities into the surface of the prototype. The prototype is also partially coated with resin. One end of the prototype is extended to its edges, but the other end is left flexible. This use of resin emphasises the structure flexibility of the uncoated portion of the prototype.

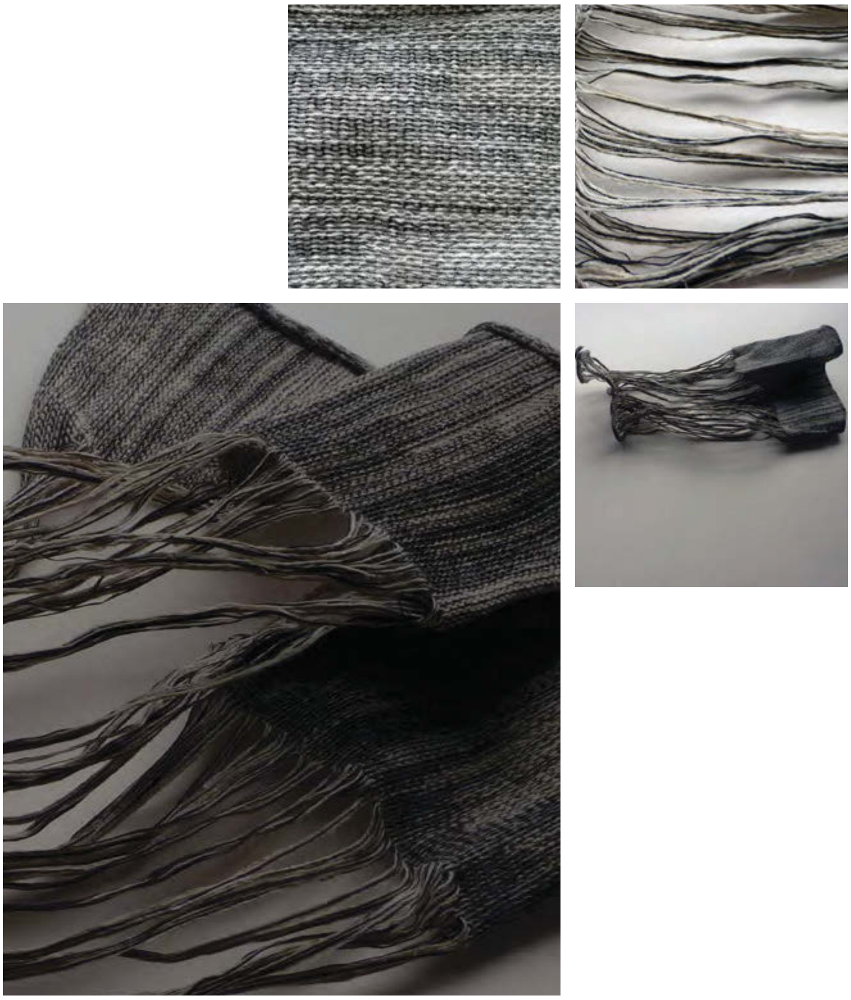


Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	4 / 120 / 360
Yarn	wool + linen
Additive	Resin

Figure 26. Prototype No. 5

Prototype No. 6

In this experiment, the analysis of the scale of floats continues and, in this instance, the prototype extends the structural boundaries and possibilities that lie within the organisation of the knit. The structure is fragmented into two parts. The first part is constituted of a single knit and floating yarns forms the second part. The linen yarns utilised in this prototype are flexible when organised into a knitted network. The long floats allow the yarns to move freely; however, as a whole, the floating surface loses its elasticity. In addition to the pre-existing stiffness caused by the knit structure adopted, a coating of a small amount of resin was applied to the knit. The result creates a rigid surface; however, the shape can still be manipulated.



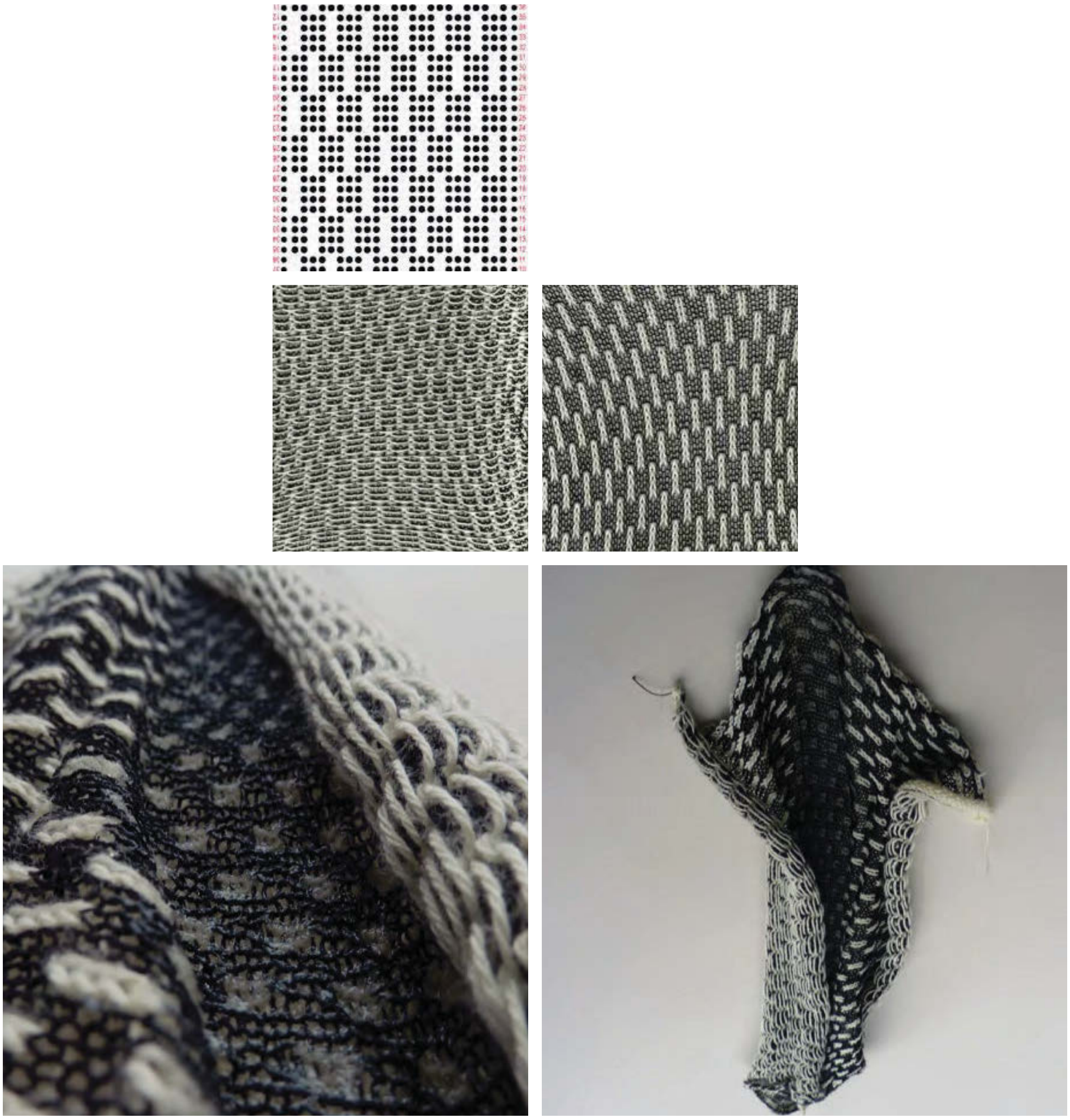
Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	3 / 120 / 200
Yarn	Linen
Additive	Resin

Figure 27. Prototype No. 6

Prototype No. 7

A Fair-Isle (knit-in) stitch is used for this prototype. This stitch implies the utilisation of two yarns to compose the knit structure. Following instructions from the punch card matrix, needles in the working position knit the main colour[21] and needles in the upper working position knit the second colour. Additionally, floats are created on one face of the knit (see image 2 in Figure 28). Prototype 7 provides a particularly interesting example for examining the punch card pattern in comparison to the textile geometry. As shown in Figure 28, the visual association between the punch card and resulting textile geometries is clear. The use of two contrasting colours of yarns (i.e. black and white) assisted in creating an awareness of the geometry within the knit structure. The application of resin is restricted to the centre of the knit surface and plays a role in its articulation.

21 The domestic knitting machine used has four needle positions: A. Non working position. B. Working position. C. Upper working position. D. Holding position.

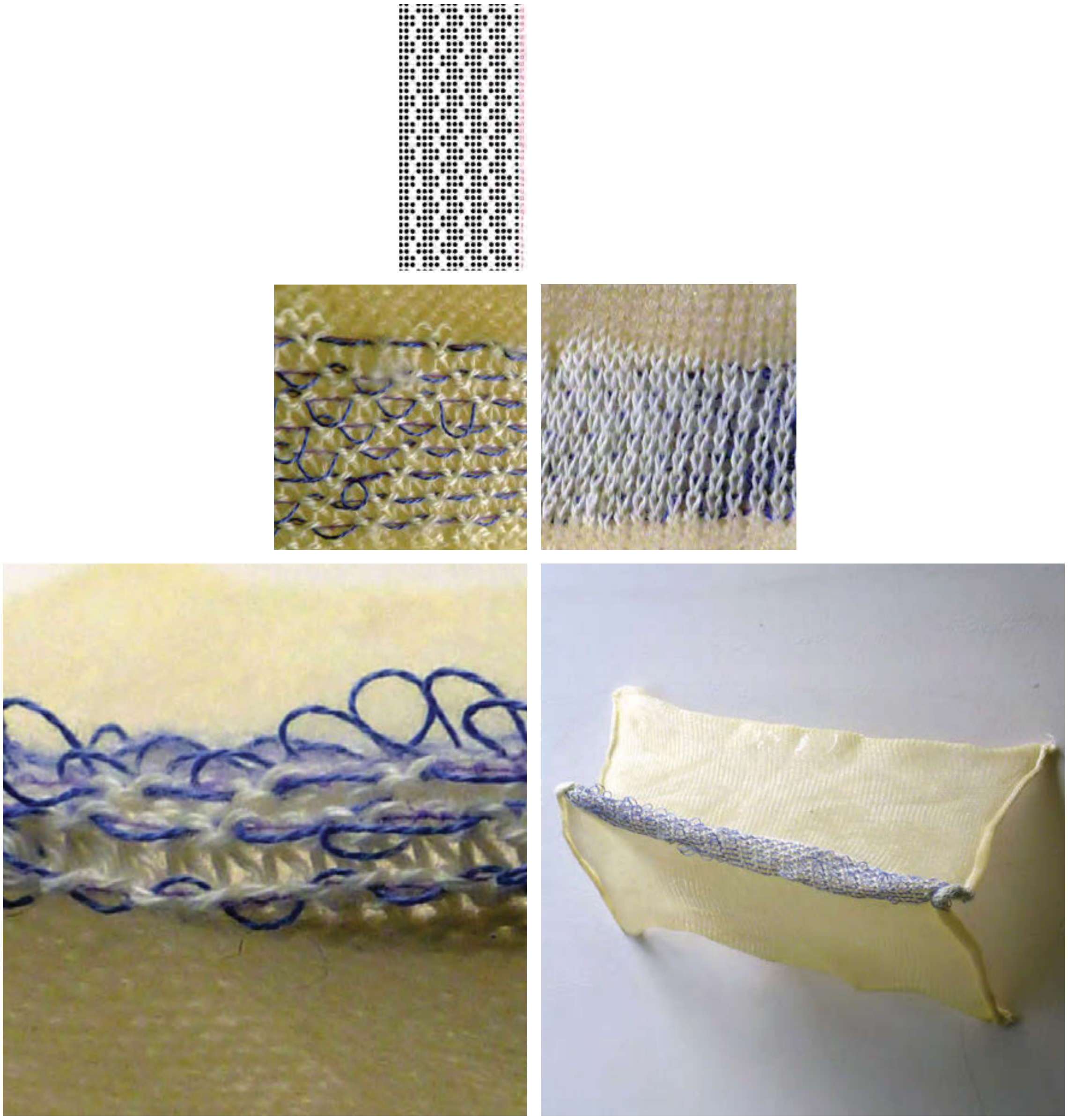


Knitting pattern	Fair isle (knit-in)
Punch card number	3.A
Stitch Dial/Width/Length	4 / 90 / 85
Yarn	Cotton combination
Additive	Resin

Figure 28. Prototype No. 7

Prototype No. 8

A Lycra yarn variation is utilised in this prototype. While the majority of the structure is formed using wool and a single knit stitch, a weaving stitch combines the Lycra with wool at the midpoint of the knit surface. Resin is then applied to the model in opposition to Prototype 7, such that only a line in the centre of the surface is kept flexible. The result is a prototype that forms two solid surfaces articulated via a flexible joint. The solidified edges of the knit restrict the motion of the structure. However, comparable to the body's skeletal system, the arrangement of the knit in two parts allows movement. Interrupting the sense of the structure as a whole, the resin divides the knit into fragments. This articulation limits the continuity of touch across the fabric.



Knitting pattern	Single knit + weaving
Punch card number	4.A
Stitch Dial/Width/Length	4 / 120 / 300
Yarn	wool + cotton + lycra
Additive	Resin

Figure 29. Prototype No. 8

Prototype No. 9

This prototype consists of two modules, varying in size and shape, joined by resin. The outcome generates juxtapositions in texture, geometry and colour. To further the investigation of material as an articulated skeletal system, the sample is then moulded around a fragment of the human body, specifically around an arm in motion. The model metaphorically reforms the elbow joint through the process of its surfaces being treated with resin. The photographic study deliberately do not depict the use of the body to form the prototype, allowing the sample to be displayed as a textile entity rather than as an envelop for the arm.

Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	6/120/300 - 4/120/310
Yarn	wool - wool + lycra
Additive	Resin

Figure 30. Prototype No. 9

Prototype No. 10

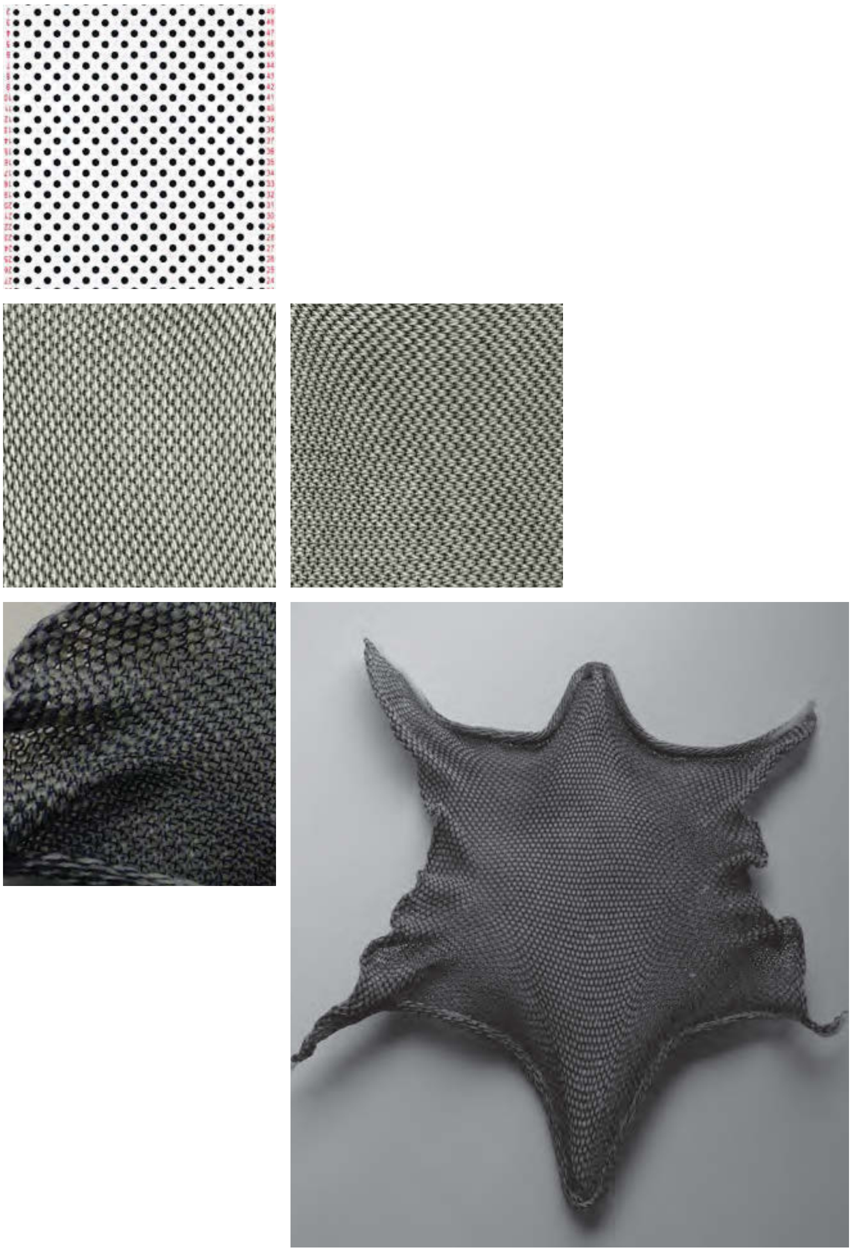
Thick wool yarns are combined with thin linen in this prototype. The geometry of the single knit stitch is illustrated on two definite scales within the structure. Three dimensions are formed using this combination of contrasting sizes. To add another level of complexity, the knit is partly immersed in resin and moulded around a human neck. The process constructs a skeleton and skin structure that moves and conveys the silhouette of a body. One part of the prototype forms a hard, structured shape; however, the other part remains soft and flexible. This interplay creates a performance. The methodology explores the potential of textiles to constantly create forms that follow the motion of a structure. To achieve this performance, the practice plays with dualities such as hard and soft, and natural and artificial materials (e.g. wool and resin). Consequently, this prototype juxtaposes numerous tactile properties. A smoothness associated with a roughness also introduces a new experience to the textile materiality.

Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	8 / 120 / 250
Yarn	wool + linen
Additive	Resin

Figure 31. Prototype No. 10

Prototype No. 11

The prototype was plunged into resin and manipulated to extend its surface to the limits of its elasticity. The modification of the geometric structure by forced stretching is fixed through the solidification of the knit. Tension is applied on six distinct points that can be clearly identified in Figure 32. In its deformity, the knit visually depicts an almost animal like surface skin.



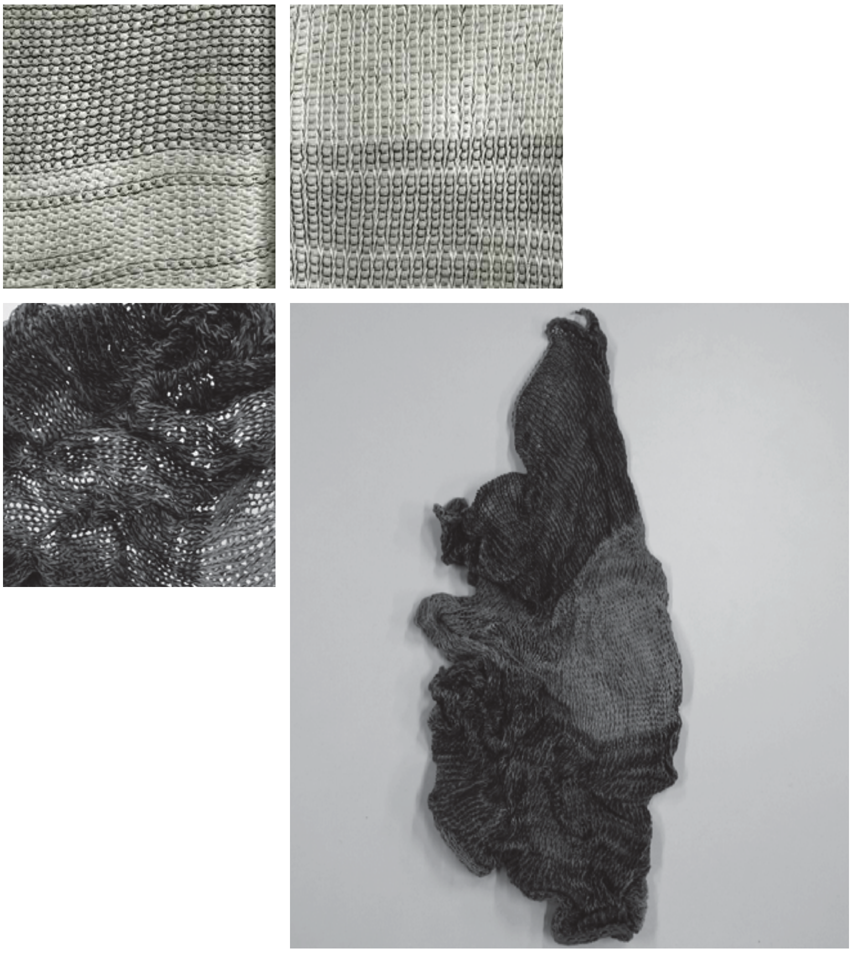
Knitting pattern	Fair isle (knit-in)
Punch card number	1.A
Stitch Dial/Width/Length	6 / 120 / 170
Yarn	Cotton combination
Additive	Resin

Figure 32. Prototype No. 11

Prototype No. 12

The use of latex additives results in different outcomes to those produced by resin. When latex additives are used, the knitted piece adopts formal characteristics and topological surface transformations can be achieved through the human manipulation of holding and squeezing. For this prototype, the geometry of the knit is fixed and a subtle solidity is attributed to the surface through the formation of creases, but the model retains a certain degree of flexibility.

The process of coating knitted textiles with latex generates interesting results for this research, as it challenges both tactile and structural properties of the knit. However, after some time, the quality of latex coating deteriorates, consequently changing the quality of the knit. To maintain a consistent record of the outcomes, the discovery of this factor led to latex being utilised only twice throughout the project.

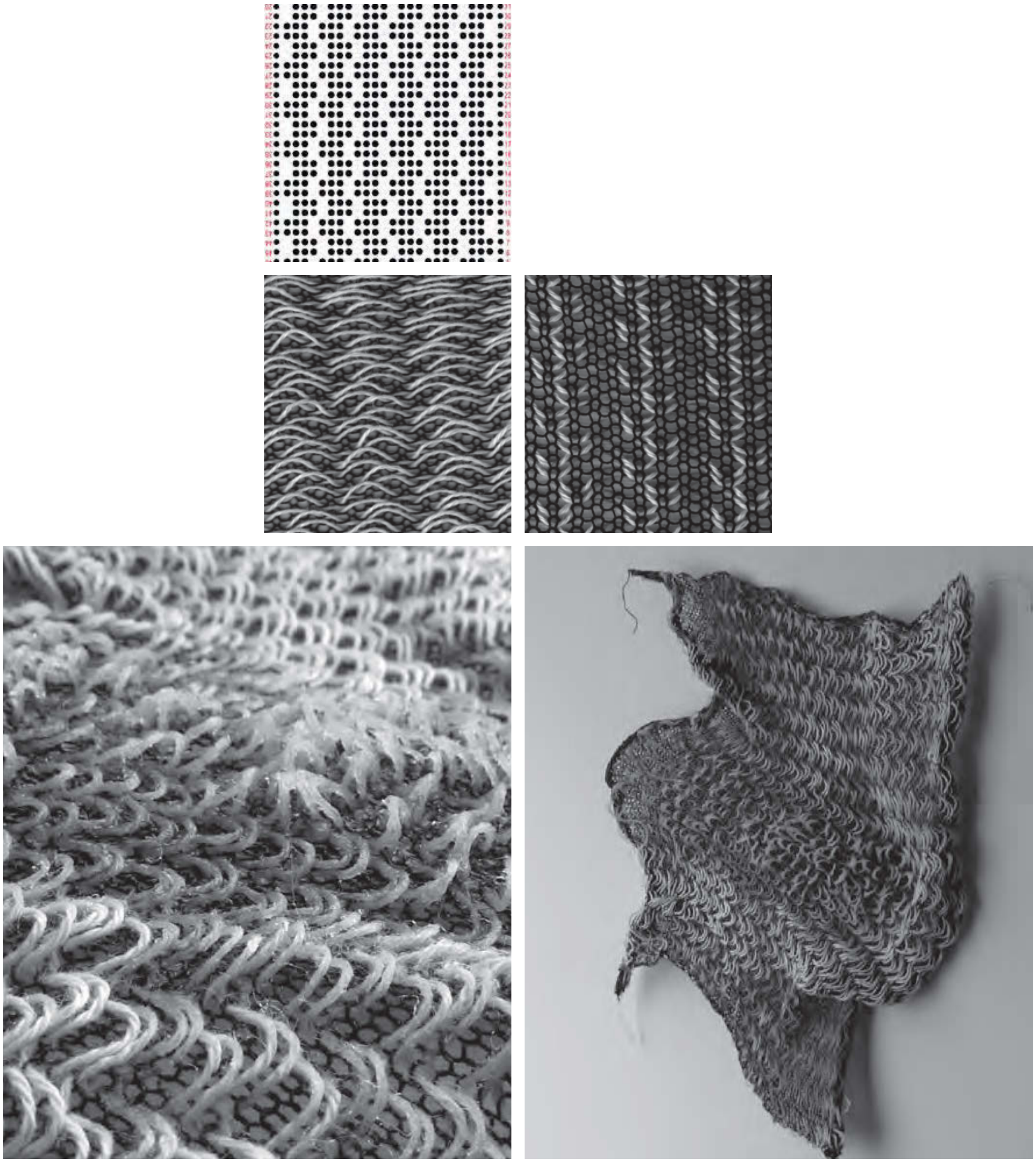


Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	10 / 160 / 160
Yarn	Cotton combination
Additive	Latex

Figure 33. Prototype No. 12

Prototype No. 13

A weaving stitch is employed in this prototype. This technique requires two yarns: a backing yarn and a weaving yarn. The knitting machine mechanically set the needles into working or upper working positions as per the instructions on the punch card matrix. The construction of this stitch necessitates the intense involvement of the maker who is required to transfer the weaving yarn from the left hand side to the right hand side of the knitting carriage and then the other way around after knitting each row. This action places the weaving yarn along the needles in the upper working position. When a row is knitted, the backing yarn knits normally, hooked by the needles in working position. In addition, the backing yarn catches the weaving yarn on the upper working needles. Consequently, floats of various intervals appear on one side of the textile, forming layers. The organisation of the prototype's structure looks like a landscape: a field of yarns.

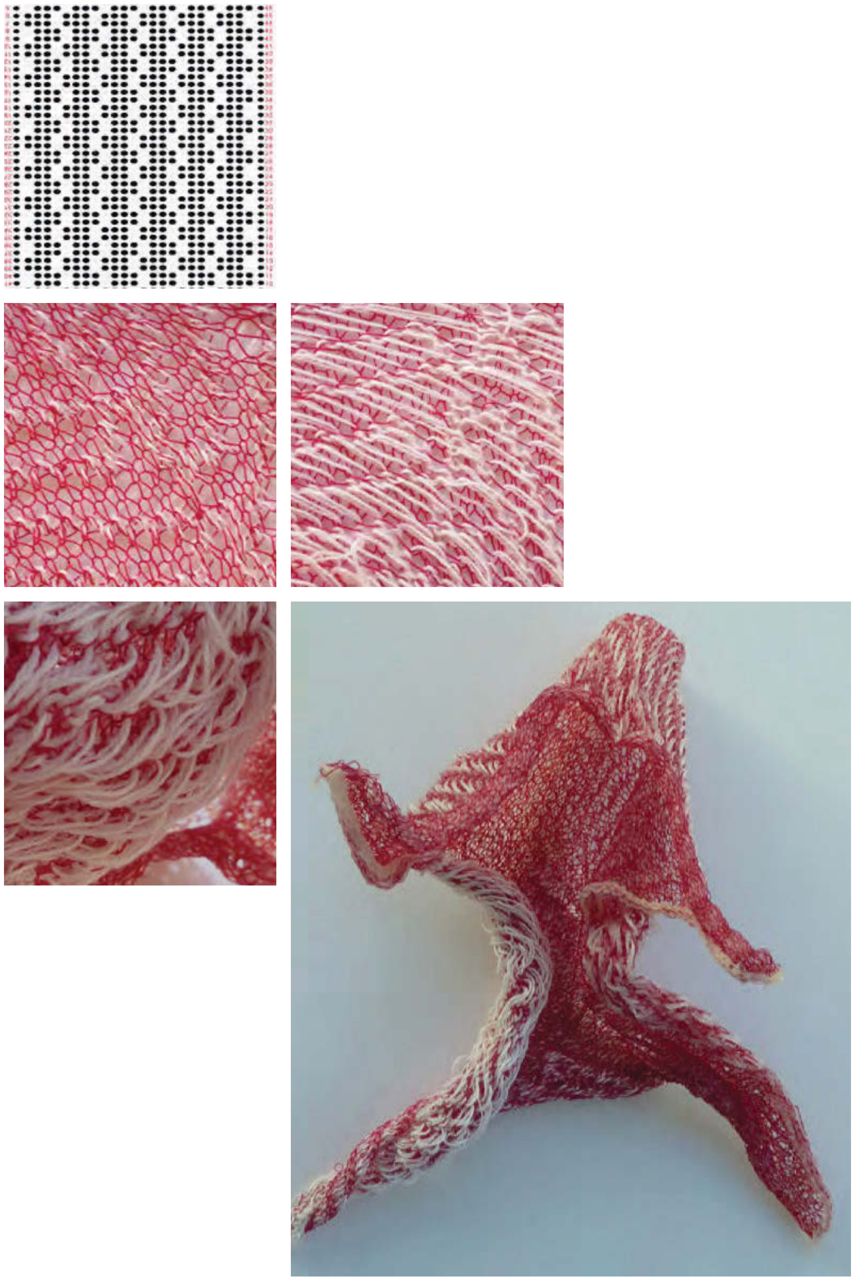


Knitting pattern	Weaving
Punch card number	4.A
Stitch Dial/Width/Length	3 / 90 / 110
Yarn	Cotton + wool
Additive	Resin

Figure 34. Prototype No. 13

Prototype No. 14

Adopting an identical production process to that used for prototype 13, this prototype is created using a weaving stitch. Two cotton yarns, red and white, are combined to contrast the knitting geometries. Defining textiles as a structure, this experiment looks at material as a spatial entity rather than a two-dimensional patterned surface. On an applied level, the spatial complexity is achieved by the formation of a multi-layered network. To create additional shapes, the sample is moulded around a random object. Through material/chemical interactions, hard and soft structures redefine the spatial organisation of the knit. The partial application of resin metaphorically creates an image of a ‘skeleton’ and ‘skin’ in the textile. The resin introduces a new experience to the materiality. It solidifies and exposes the structural layers of the prototype and their geometries, but results in a divergence from the anticipated tactility of the knit.



Knitting pattern	Weaving
Punch card number	4.A
Stitch Dial/Width/Length	3 / 90 / 120
Yarn	Cotton combination
Additive	Resin

Figure 35. Prototype No. 14

Prototype No. 15

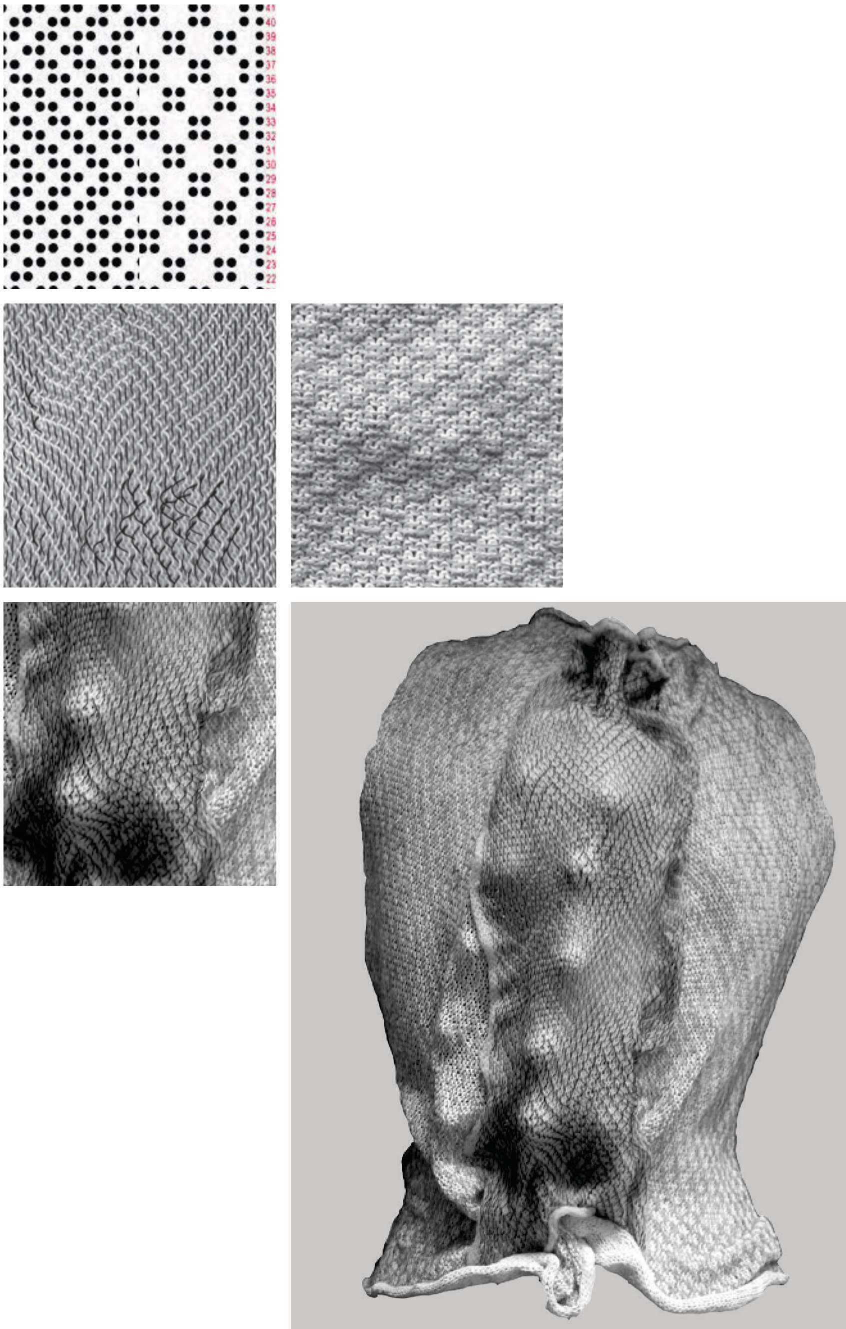
The weaving stitch is further investigated in this prototype using a white yarn and a grey yarn. The weaving stitch is important to the methodology of this experiment as it displays the potential of knitted geometries and their ability to produce spatial organisation within their structures. Each picture visually links the material outcome with the geometry of the punch card. Further, the grey yarn follows the pattern of the punch card creating a path through the structure of the knit. The prototype is entirely plunged in resin and moulded onto a random form. The experimentation aims to alter the material and re-form it. The solidification of the yarns both materially and visually creates a landscape. The resin exposes the complexity of the construction via a fixation on the geometry. By physically altering the natural structure of the knit, the resin dictates shape and reveals the potential for transformation.

Knitting pattern	Weaving
Punch card number	8.A
Stitch Dial/Width/Length	7 / 150 / 150
Yarn	Cotton combination
Additive	Resin

Figure 36. Prototype No. 15

Prototype No. 16

This prototype combines two surfaces, varying in size, each formed through separate stitch constructions: weaving and punch lace. The combination of the two stitches led to the model having two geometries. Both surfaces are plunged into two opposing additive treatments: latex and resin. Each additive generates a definite type of materiality. Resin, utilised on the upper section, creates a solid model. Latex, applied to the under layer, provides a malleable coating. Chemical treatments bond the component layers together. The prototype expands the field of investigation through the use of the body form as a topographic entity. Moulded onto a human silhouette, the resulting textile object redefines a fragment of the body's form through the materiality of the knitted geometries.



Knitting pattern	Weaving - Punch lace
Punch card number	8.A - 2.A
Stitch Dial/Width/Length	7/120/150 - 6/120/340
Yarn	Wool + Cotton
Additive	Resin - Latex

Figure 37. Prototype No. 16

Prototype No. 17

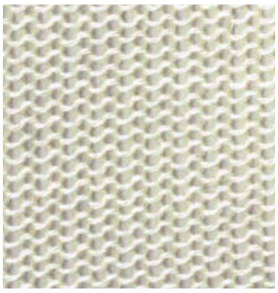
Form defining during the knitting process is the aspect of textile production explored in this experiment. In the construction of this prototype, the methodology enters a new stage, which aims at building knitting structures that become three-dimensional through their own strength. The practice utilises layering as a process for replacing additive treatments. This method of layering is used to create folds within the prototype. As Quinn (2003, p. 215) states, ‘a fold changes everything. It bring surfaces together while simultaneously dividing them, or bends them one into the other as it organizes the space they occupy.’ Two similar surfaces, both built with wool, are grafted together and take form during the knitting process.

Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	3/90/250 - 4/110/270
Yarn	Wool
Additive	nil

Figure 38. Prototype No. 17

Prototype No. 18

The same technique used in prototype 17 is employed for prototype 18. The idea of layers is the starting point for form finding through knit construction. However, in this prototype, a thick wool yarn forms the first knitted surface, while a thinner linen yarn is grafted onto it. Volumes emerge from the surface combinations and the folds created in the process. The representation of topographical complexities creates a field of yarns (see Figure 39). The creation of folds generates a three-dimensional structure with various spatial depths. Additionally, it allows the material to keep its tactile properties and natural elasticity throughout the metamorphosis.




Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	5/110/250 - 8/110/260
Yarn	Wool + Linen
Additive	nil

Figure 39. Prototype No. 18

Prototype No. 19

Following a logical approach, the methodology continues to use layering techniques to build three dimensions within knitted structures. However, the construction of prototype 19 focuses on the density of yarns rather than the layering of surfaces. Cotton and Lycra, both of which have elastic properties, are utilised to create complexity within the structure. This experiment returns to the basic definition of knitting, which defines a structure composed of multiple loops of yarns. As Emery (1994, p. 45) states, ‘The word loop suggests the curved enclosing boundary of a space’. By extending the formation of the loops to a broader scale, the yarn network is amplified through the formation of floats. The floats provide a certain level of freedom of motion to the structure. Further, this formation of ‘space’ allows for a photographic exploration of the spatial potential of the network of yarns (see Figure 40).




Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	5 / 90 / 100
Yarn	Cotton + Lycra
Additive	nil

Figure 40. Prototype No. 19

Prototype No. 20

This prototype seeks to explore the transformation that occurs when two-dimensional surfaces meet three-dimensional shapes without the use of post-knitting additive treatments. To achieve this goal, a new kind of raw material (that is both strong and malleable) is introduced into the knitting process: nylon monofilament. A prototype is created using a basic single knit structure that combined wool yarn and plastic yarn. The association between the two types of yarn creates synergies, contrasts and tensions that generate a three-dimensional structure. Additionally, the textile reveals properties for transformation. Upon manipulation, it opens up and metamorphoses into a larger object. The knit become a 'body' and motion occurs within the structure. Different patterns are created in the sense of geometry and movement. Responding to motions (active and passive, solid and flexible, opened and closed), the yarns balanced their differences to create structure within the knit.

Knitting pattern	Single knit
Punch card number	nil
Stitch Dial/Width/Length	6 / 90 / 120
Yarn	Wool + Nylon
Additive	nil

Figure 41. Prototype No. 20

Form Finding

This chapter illustrated how the characteristics of textiles are determined by their fabrication. The material was considered as a system of capabilities, and different construction and post-knitting methods were utilised to shift its physical properties, such as flexibility and texture. The methodology explored experimental form-defining processes and the dialogue that exists between the knitter and the constructed materials. Direct interactions during the construction of the knitted structures allowed the knitter to have complete control over the materiality of the textiles created. The reconditioning of textiles with the use of additives permitted to explore the transformation from two-dimensional surfaces to three-dimensional forms. Having thus set the focus of the study on formal and tactile aesthetics, the research then seeks to further explore the intimate nature of the relationship between textiles, body and space.

Chapter 3: HUMAN FORMING GEOGRAPHY

Exploring Human Geography

Gregory, Johnston and Pratt (2009, p. 287) state,

> Literally, 'earth-writing' from the Greek geo (earth) and graphia (writing), the practice of making geographies ('geo-graphing') involves both writing about (conveying, expressing or representing) the world and also writing (marking, shaping or transforming) the world.

The application of this definition to the human form was adopted for the purpose of this research. The study considers the body and the geography of the human figure in motion in its relationship to ground and in its interplay with its surroundings. In an essay entitled 'An Architecture of the Seven Senses', Juhani Pallasmaa[22] describes bodily experiences by referring to the action of walking; 'we trace the density and texture of the ground through our soles' (2006, p. 33). The relationship between body/weight within the realities of gravity is the experience explored. Further, examining the way bodies consciously or unconsciously sense their environment while in motion, Pallasmaa (2006, p. 35) states,

> As we open a door, our body weight meets the weight of the door; our legs measure the steps as we ascend a stair, our hand strokes the handrail and our entire body moves diagonally and dramatically through space.

Taking human motion and geography as a beginning point for exploration, this section focuses on the practical relationships between movements and their interplay with textiles. Topography is generally defined as 'a detailed description or delineation of the features of a locality' (Oxford University Press 2000). However, in this study, topography is understood as a

22 Finnish architect, Juhani Pallasmaa further elaborated on the topic of perception in his 2012 book: *The Eyes of the Skin: Architecture and the Senses.*

representation of the surface features of the body's silhouette in motion. Yarns become mediums on which to write 'maps' and follow 'paths' that have been implemented on the site of the body through knitting processes. The research methodology advanced the structural characteristics of knitted textiles to create 'landscapes of forms'. The reconditioning of textiles through chemical additives developed moulds of the human body and its features can be used to reproduce conditions for human textile topographies.

Clothed Landscapes

When textiles are confronted with the three-dimensional form of a human body, an interaction occurs that includes the back and forth between skin, the textile's texture, body movements and the textile's structure. How does this performance evolve with the application of textiles? Does a new concept of human space appear? Do textiles generate new notions of spatial appearance beyond the human form? These interrogatories address the potential of reforming the relationship beyond textiles and the body in the between space. They also set up the next step in the research methodology. The research explores the concepts of enveloping, cocooning, shrouding and reconditioning the body to reveal new possibilities in the creation of forms. Further, enveloping is investigated and considered as 'an act that probes existing things and turns them in on themselves (...) to open up new approaches to them through their changed aspect' (Ronte 2004, pp. 22–3)[23].

A photographic study was undertaken to explore the human silhouette so that the body as a form connected to geography could begin to be rethought. This visual study (see Figures 42 and 43) intends to reconcile (through the materiality of textiles) the dialogue between the human figure (a construct of curvilinear surfaces and fluidity) and the motion of human movement over

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23 In the context of the book, *Christo and Jeanne-Claude: International Projects*, Ronte refers to Christo and Jeanne-Claude work of concealing buildings and landscapes. The act of covering with fabrics reveals and highlights new features of the concealed.

various undulations of terrain. The construction of an envelope for the body and its movements introduces new dimensions of spatial depths through the formation of folds.

The photography work explores the nature of the folds as a creation of space developed through the body's motion. As Barnett (2012 p. 183) explains, '...To fold and unfold and enfold... this is a space to curl and to clasp, to enclose, and to disclose: a space of encounter...'. The photographs map the folds and bring to the fore new features. When the body's form is revealed and understood through the material, our perception and relationship with human geography is challenged.

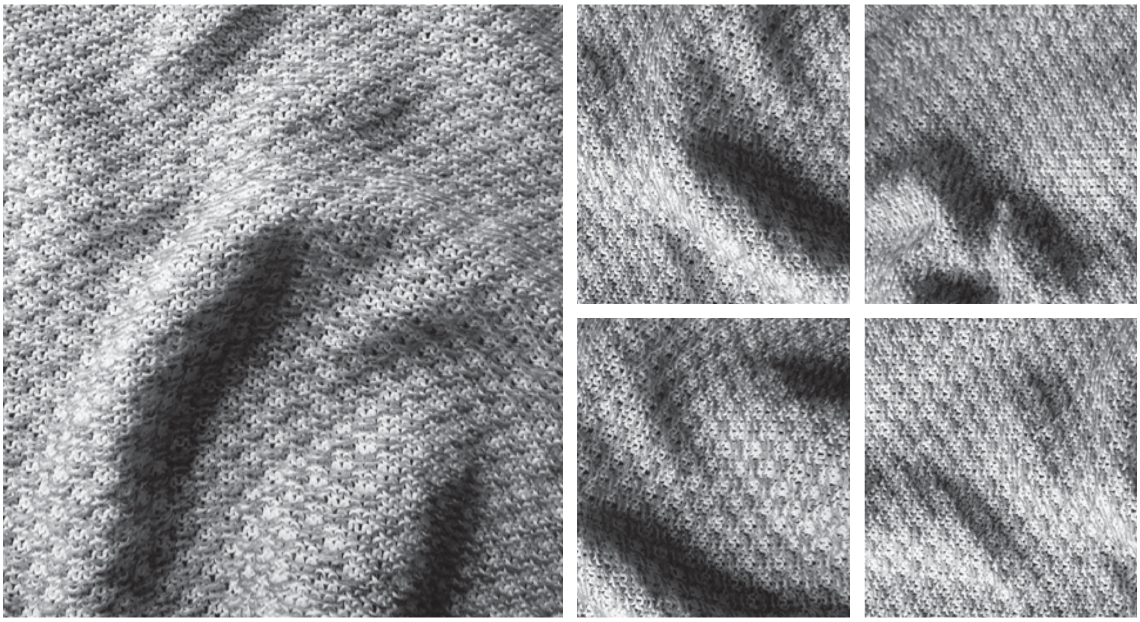

Figure 42. Clothed Landscapes 1—Photographic investigation

As Manning[24] (2009, p. 33) states,

> Folding undoes the finality of form. Form becomes a folding into, a force-toward that is a threshold, a becoming-spiral, a becoming-turn, a becoming-triangle. These are forms-in-the-making, resonant only in relation to the movement they give rise to.

The folds created through motion are not spatially fixed, but it is in their depths and variations that the spatial form appears. Bodies and materials merge to create combined systems that operate as a generator of spatial geometries. To understand and develop these systems, the next section investigates the moving body and its relationship with textiles.

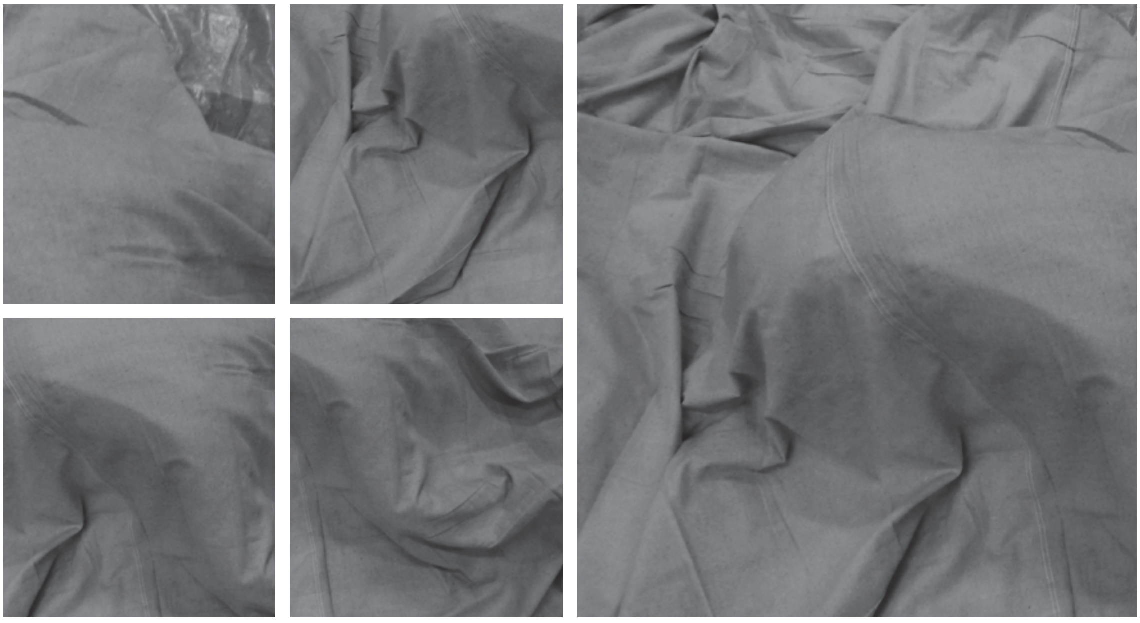

Figure 43. Clothed Landscapes 2—Photographic investigation

24 Erin Manning is a researcher in Relational Art and Philosophy in the Faculty of Fine Arts at Concordia University, Montreal. She is the founder and director of 'SenseLab', a laboratory that explores the connections between art practice and philosophy.

Mapping the Body

The structures and mechanisms of the body lie underneath the tissue surface of the skin. This hidden anatomy includes bones, articulations, muscles and organs. While the skeletal structure is the framework for movement, 'the skin reads the texture, weight, density and temperature of matter' (Pallasmaa 2006, p. 33). The skin is a sensing covering organ that develops a primary interchange with textiles. As the body's largest organ, the skin mediates the sense of touch, heat and sweat. As an envelope that protects the interior of the body, the skin has an inside/outside conflict; it has the presence of an outside covering, but is positioned inside the body. Fend (2005, p. 311) states,

> One of the paradoxes of the human body is that its most extensive organ presents itself externally. I refer, of course, to the skin, which is both part of the body and also its delimitation.

A multi-layered boundary and connection between an unknown interior and an exterior, the skin marks both the inner and outer limitations of the body as well as its threshold. Lupton[25] (2002 p. 29) notes that skin 'lacks definitive boundaries, flowing continuously from the exposed surfaces of the body to its internal cavities'. The focus on these inside/outside dualities of the human body constructs a form-defining programme of inter-relationships. The exploration of these relationships and their transference into the materiality of textiles is the objective of this chapter. Lupton (2002 p. 208) also states that,

> Skin is a two-dimensional surface that wraps around the volume of the body. Sometimes it is taut, clinging tightly to the musculature beneath, and sometimes it is slack, hanging in loose folds.

A metaphorical approach towards skin assimilates its function and materiality with textiles. Textiles have often been described as second skin for the body while architecture has been defined as its 'third skin'. This study questions the characteristic of skin being spatial, alike a surface that moves back and forth between the body and its surroundings.

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25 Ellen Lupton is curator of Contemporary Design at Cooper-Hewitt, National Museum and director of the Graphic Design Master of Fine Arts programme at Maryland Institute College of Art in Baltimore.

Turney[26] (2009, p. 108) wrote that: 'Knitting and the knitted object are indicative of revealing and concealing, and creation of a deliberate juxtaposition of the inside/outside, front/back, plain/purl'[27]. The materiality of textiles creates a dialogue between a person and his/her environment. Comparable to skin, textiles act as interface that connects the body. Turney (2009, p. 109) also noted that: 'All fabric has a close proximity to the skin: textiles are worn, sat on, walked on, and as such as constantly subject to sensory and bodily interaction'. Thus, the network of yarns that organises a spatial enclosure around the body generates surfaces with no boundaries; rather, the surfaces form transitions and connections that are particularly felt through the sense of touch—skin and textiles combine.

The Moving Body and its Relationship with Textiles

A conception of space appears when textiles follow the fluidity of human movement. Working with the human figure, enables a continual creation of new forms and the formulation of motions. Textiles can be viewed as 'actors' caught in a 'play' between body and movement. The body lends to textiles its form and life. This research considers constant motion as a methodology for constructing textile forms.

This study was influenced by Muybridge's photographic investigations of the body and his exploration of the body's mechanics in relation to motion. His photographs suspended motions in time and recorded attitudes of the human body. Various selected movements were depicted as a series of actions. To further understand the behaviour of textile structures and their relationship with a moving body, this research undertook its own motion study. The photographic study explores the structural behaviour of textiles as applied to the human figure in motion. The process is divided into two stages. The first stage explores the phase of *becoming*, as a continuous motion

26 Joanne Turney is senior lecturer in History and Design at the Bath School of Art and Design.
27 'Plain/purl' refers to the structure of single knit stitch. The two sides of the stitch look different. The face of the knit is called plain and the back is called purl.

(a movement between movements) from one moment to the next. The second stage explores the *completion* of a movement, captured through photography; the motion is visually immobile and caught the materiality of the textiles. Looking at the various paths of motion, the series of photographs illustrates the attitudes taken by the textiles and defines hints of movement. The photographs are collected into sequences and selected movements are mapped in space.

Figure 44. Study of Motion—Knee, Hip, Elbow and Shoulder

Chosen movements were associated with four parts of the body: knee, hip, elbow and shoulders. The skeleton permits the human body to set into motion. An articulation, also known as a joint, is a fragment of the skeleton where bones intersect and allow movement. The photographs act as mediator of motion, comparable to chemical additives, they fix the geometry of knitted structures. The utilisation of additives can be considered as a macro exploration of textile structure, while the photographic study explored the behaviour of textile structures on a bigger scale. Stepping away from the structured geometries, textiles are studied in relation to their application on the body in an outdoor environment. This situation involves potentially uncontrolled topographical features such as landscapes and atmospheric conditions. The textile behaviour was subject to and dependant on the moving body in its environment. The project investigates and explores the nature of the textile folds created through the body's motion. Quinn (2003, p. 215) states, 'As an expression of form, the fold produces its own architecture by creating a site that enfolds structurally'. The photographs visually reveal the implications of folds in enveloping, concealing and revealing the body's movements.

To complete this brief review on human locomotion, the research investigates another analysis on motion by a contemporary of Muybridge, Etienne Jules Marey (1830–1904). In 1882, a French scientist and physiologist, Marey invented chronophotography, the predecessor of cinematography. Chronophotograhy is a photographic technique that captures sequenced images of motion. In comparing Muybridge and Marey's works, Manning (2009, p. 108) notes,

> While Muybridge's images look like cinematic stills, it is the movement's interval and duration that is palpable in Marey's images, rather than the actual stills themselves. In Marey's work, duration is felt, whereas in Muybridge, duration is divided. Muybridge's images do not incorporeally flow into one another, and are in fact often shuffled for narrative purposes.

Marey's photographs are of interest to this study as they map the human geography in motion. As a trace of movement, ‘the line does not simply represent movement: it creates the feeling of movement’ (Manning 2009, p. 89). His investigation on the human body in its connection to the ground informs the research methodology in relation to the creation of textiles and their relationship with body motion. Moving on from the representation of human movements through solidified textiles, this research focused on creating a textile prototype with a potential for transformation.

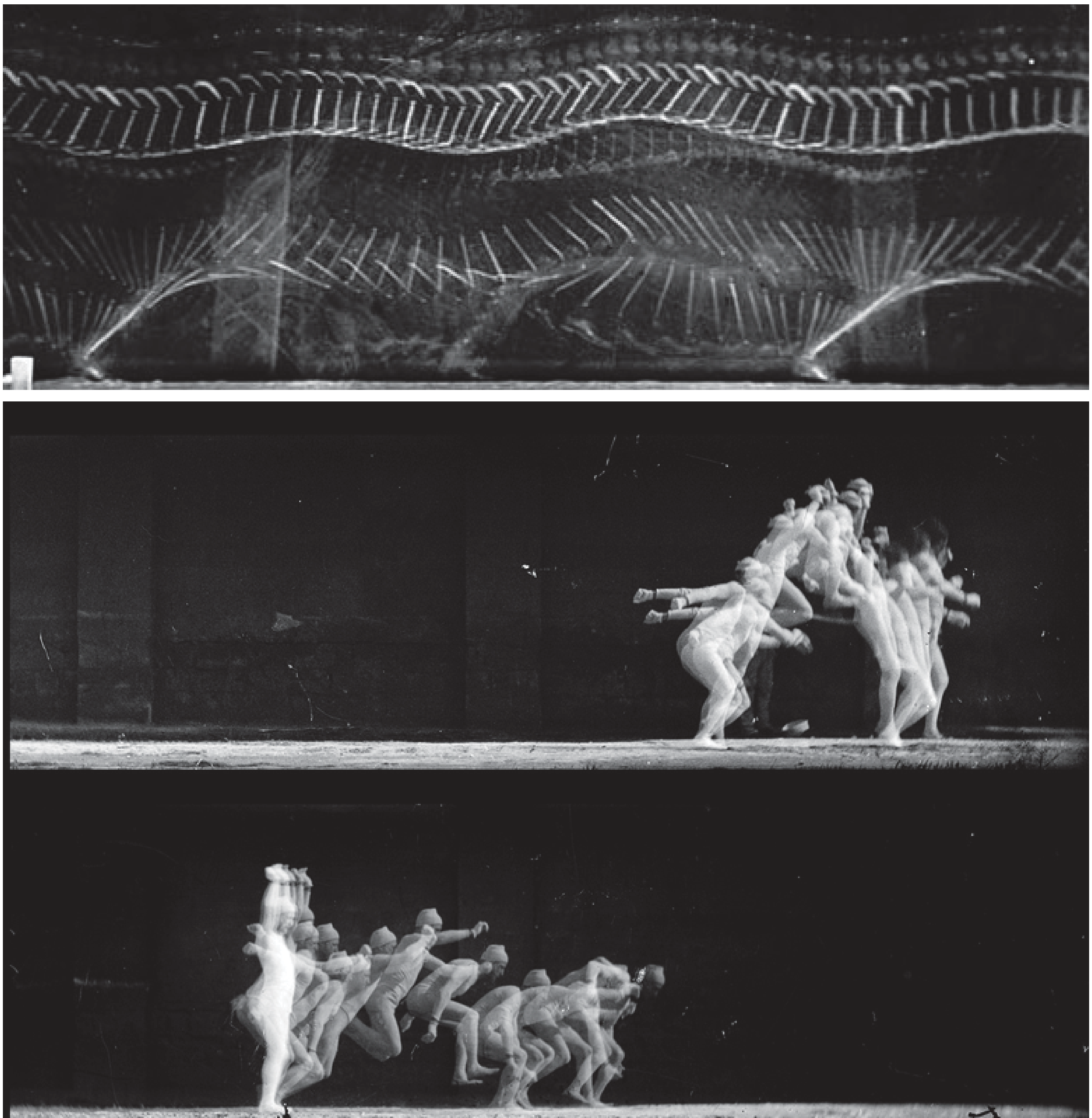

Figure 45. Images produced by Etienne Jules Marey (in the late 1800s)

Source: 2015 <http://www.facstaff.bucknell.edu/efaden/130/taylorism.html>

Siobhan Davies Dance, 2015 <http://www.siobhandavies.com/whats-on/film/all-can-happen-school-sound/>

Projection

Physical and Experimental Creation of Space

As Merleau-Ponty[28] (1962, p. 117) states,

> It is clearly in action that the spatiality of our body is brought into being, and an analysis of one's own movement should enable us to arrive at a better understanding of it. By considering the body in movement, we can see better how it inhabits space (...).

This research uses the body to consider the creative process, which informs the practicality of exploring the potential of textiles in the third dimension. The moving body becomes the site of implementation in which body boundaries are challenged to create space. As Manning (2009, p. 13) states, 'We move not to populate space, not to extend it or to embody it, but to create it'. While the ground is the basis for the body's movement, human geography belongs to the way we shape the earth and this research considers how the body shapes textiles.

In his book entitled 'The Poetics of Space', French philosopher Gaston Bachelard (1884–1962) studied the lived experience of architecture and wrote about '*L'oiseau*' the 1858 work of French historian Jules Michelet (1798–1874). As Bachelard (1964, p. 101) states, 'Michelet suggests a house built by and for the body, taking form from the inside, like a shell, in an intimacy that works physically. The form of the nest is commanded by the inside'. In developing this idea, Bachelard (1964, p. 101) quotes Michelet:

> The instrument that prescribes a circular form for the nest is nothing else but the body of the bird. It is constantly turning round and round and pressing back the walls on every side, that it succeeds in forming this circle.

Undoubtedly, the utilisation of the body as a measuring system is not

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28 Maurice Merleau-Ponty (1908–1961) was a French phenomenological philosopher. Originating in the twentieth century, phenomenology was a philosophical movement that studied 'the structure of various types of experience ranging from perception, thought, memory, imagination, emotion, desire, and volition to bodily awareness, embodied action, and social activity, including linguistic activity' (Smith 2013, para. 8).

peculiar to birds. As Pallasmaa (2006, p. 34) states, 'the builders of traditional societies shaped their buildings with their own bodies in the same way that a bird molds its nest by its body'.

This chapter reflects on the human body in motion and its surrounding space, however, the concept of spatial interaction has been materially explored within this research through the vehicle of textiles. The primary work, recorded in the technical file, illustrates a contemplative approach to how the body engages with space through motion during construction and post-knitting additive processes, which interrupt the textiles. More specifically, in my exploration, the body lends its form and motion to textiles. Firstly, the body of the maker is fully engaged in the textile construction through the knitting machine process. Secondly, in post-production, interactions occur with the material through body gestures and three-dimensional form is given to the knitted structure.

This combination of textile material and body performance is fully explored in Chapter Four. This study works on the creation of the bodily experience that occurs when textile materiality is activated through the participation of a user. The aim of this research is to create a sensory experienced structure that function as a foundation for spatial organisation, a detail of topography.

Chapter 4: MOTION DEFINES FORM

The next phase of practical research aims at creating a prototype in which material and three-dimensional forms could be created simultaneously. In other words, when the textile construction process shapes the final object. While additives were a good asset to explore knitted structures and their spatial organisations in the primary stage of the research, their application requires post-construction treatment. Additionally, additive processes generate permanently solidified structures, which create limitations for the study of spatial interaction between textiles and body. To continue the material explorations from prototype 17 to 20 (see technical file) and the investigations in Chapter Three, the methodology does not aim to permanently solidify the structure of the knit, rather, the methodology evolved from forming textiles through the use of additives, to forming transformative structures.

This chapter explores notions of metamorphosis, conceptually as well as materially. In doing so, it focuses on three defined themes: object, body and space. Each theme leads the discussion to interrogate scale and considers 'the ways in which different scales offer us different kinds of experience' (Martin 2000, p. 82).

Questioning Parameters

Object

To discuss scale and consider the presence and role of objects in textile forms, the research first observes the general definition of an object as 'a material thing that can be seen and touched' (Oxford University Press 2000). Textile objects commonly function as coverings or envelopes for the body and its surroundings. An object may be smaller or bigger than a human figure and shows possibilities to be held and controlled by the body. Martin (2000, p. 79) wrote: ‘We are embodied beings who see and touch, perhaps picking up or walking round a physical presence’. Textile items may act as triggers for physiological interactions and can open up and become something else. As Bergson (2007, p. 6) states, ‘The objects which surround [the] body reflect its possible action upon them’. The potential of textile objects to metamorphose and vary scale can be visualised through the example of an everyday object: a blanket. A folded blanket can be opened up at different stages to bigger scales. In unfolding these layers, only body gestures connect one scale to another. From the size of a book to the size of a proximate envelope for the body, a blanket can also be arranged to form shelter.

Body

As revealed in previous chapters, the human body in motion formed the focus of this analysis. Mechanisms of the skeletal system and perceptions of its operation were considered in Muybridge and Marey’s photographic works[29]. Further, interest is given to the body in relation to its environment, in particular in its interplay with surrounding textiles. Scale is experienced and measured through the body’s actions. As Pallasmaa (2006, p. 35) articulates, ‘we behold, touch, listen and measure the world with our entire bodily existence and the experiential world is organized and articulated around the center of the body.’ Considering Pallasmaa’s description of architecture as ‘a projection of the human body and its movement through space’ (2012, p. 49), this study reviews the hypothesis that textiles are a form of architecture for the human body[30].

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29 Please see Chapter Three: Human Forming Geography, ‘The Moving Body in its Relationship with Textiles’

30 This notation was established in the Literature Review.

Space

Beyond the scale of the body is ‘the scale of architecture, by which we ourselves become enclosed and contained. This is an inversion of our relationship with the handful’ (Martin 2000, p. 81). The inhabitation of textiles forms the beginning of this enclosure.

Space is the spatial relationship between objects and bodies. A spatial relationship can be altered by motion, ‘a cycle of constant interchange between void and mass is enacted’ (Quinn 2003, p. 82). A human body becomes aware of things through the senses and can indicate direction in space by a gesture, a movement across the space or by arranging things around itself. As an interval or a gap, space is considered as ‘the dimensions of height, depth, and width within which all things exist and move’ (Oxford University Press 2000).

Through the exploration of knitted textiles with three-dimensional qualities, the research aims to bring the scale of enclosure closer to the human body and create a sensory experience of spatial organisations.

Defining Parameters

Structural Properties

From a practical point of view, this study explores the potential for physical transformation (i.e. opened-closed-expanded-contracted) and seeks to examine the performance of knitted textiles through metamorphoses. As Martin (2000, p. 79) states, ‘The scale of making of a piece relates fundamentally to the tools that create it, and also to the human body that controls and guides’. The use of a single bed domestic knitting machine presents scale restrictions in relation to the textiles created; however, this machine was chosen for the study. Despite its size limitations, the capabilities of the machine can be manipulated. As illustrated in the technical file, the textile surfaces can structurally be grafted together, such that the knitted forms can be expanded in size.

Forms are created without the use of chemical additives when materials, such as nylon, are used in their place to produce structural solidity within the textile structure. However, the experiments aim to create textiles that are able to follow motion. Thus, a body is required to set these textiles in motion. As Manning (2009, p. 92) wrote: 'To experience the feeling of a form is to experience force taking form'. Therefore, motion gives shape to the structure.

Body Shaping Textiles

Subsequent to the methodological experimentations and reinterpretations of textiles' physical properties, the research focuses on producing a bodily experience of materiality. The three defined themes, object, body and space, explored in this chapter lead the project to the creation of a textile structure presenting aptitudes for transformation. The knitted prototype transits from one shape to another when force is applied to its structure. The geometric topography of the knit (i.e. the void between its structural elements) is viewed as an invitation to manipulate its form. Body movements generate space while activating the textile object created. Through force, movements inform the embodiment of the textile and alter the spatial organisation of its structure. In this study, body motion shapes textiles rather than textiles shaping the body. The formation of form takes place through motion.

Exploring Material Transformations

This section illustrates through visual representations, an analysis of the prototype created. A combination of Prototype 19 and 20 (see technical file figure 40 and 41), the structure uses layers of textiles to reveal spatial organisations that can appear and disappear through movements. Modules, knitted together, form a geometric field. The size of this abstract topography encourages interaction with the human body. Constraints on movement within the structure set limits on a user's behaviour, but incite the user to push and pull the knit within its boundaries. The form follows the body. Indeed, the movements of the participant mold the textile and interactions with the knitted structure challenge its geometry. Employed to explore movement activated spatial organisations, the body's interaction with the textile emphasises the topological dynamics of the structure.

Figure 46. Object

Figure 47. Body 1

Figure 48. Body 2

Figure 49. Space

Chapter 5: SUMMARY

Manipulating Textiles Properties

This study focused on tactile and formal aesthetics. Material characteristics, such as texture and flexibility, were challenged and shifted throughout the methodological processes so that a new approach to knitted textiles could be introduced. In particular, experiments were conducted that altered the materiality of textiles while focusing on their structures. Specifically, this study investigated the way in which knitted structures could be used to uncover new qualities of depth and dimension so that we could rethink our awareness and perception of their spatial organisation.

The study used knitting in its experiments, a medium that is not passive. Progressing through the methodology, the project followed the notion that 'materials hold the key to the creative process' (Danilowitz 2000, p. x). The interplay between yarns and structural geometries was followed to uncover the aptitudes of the materials and open up new dimensions in perception. With this awareness, knitted forms were developed through the constant dialogue between the raw materials, the tools and the maker. The yarns and structures, each chosen for their peculiar properties, have a certain degree of freedom in the formation of the final shape of the textile. The process of defining forms followed the properties of the yarns and their interaction with the structural geometry.

Using hand manipulations to shape the material, the first experimental stage led to explorations of flexibility and solidity through the use of chemical additives. The utilisation of additives created a better understanding of the network of yarns that forms a particular knit. In making structure solid, one becomes aware of its geometry. By acquiring a better knowledge of how textiles are built, the research uncovered a different point of view on their materiality and gained better understanding of their formal capabilities.

Mapping the Human Form

The practice-based explorations of textile materials allowed for their structure to be re-appropriated while defining their potential for form making. Further, material explorations focused on the relationship between the human body in motion and the potential of textiles in spatial construction.

To gain a better understanding of the human locomotion, Chapter Three explored the geography of the human body in motion. This exploration led to investigations into the creation of folds and their potential for spatial organisation. As Quinn (2003, p. 215) states, 'The fold is understood in terms of surfaces, yet the void manifest within its central recess is ever present'. Developments in relation to body motion defined the focus of this research in terms of the body's performance. Specifically, this process involved constant creation and brought continuous change to the textile forms. Textile properties address the body and its experience of materiality. Conversely, form defining develops at a second stage, when a textile encounters a moving body.

Spatial Structure

To extend the investigation of the human motion and its impact on geometrical construction, a body related structure was developed. The manipulated textile's materiality led to multiple characteristics, such as enclosure or mobility, being created. Highly flexible in terms of scale variations, the structure is able to respond to body movements. Further, the material explorations used the body and its actions to define form. Thus, body motions gave form to the prototype. The creation of a metamorphosing structure, allowed the textile to take form through the force of movement.

The methodology evolved, such that a knitted form was built that became three-dimensional through its own tension and stability. The creation of a bodily-animated structure developed a spatial system that is open to change. A reflection on knitting structures and their geometries, the system materialises lines in space, which create a space that is yet to come. Spatial organisation is established by the definition of relationships within the structure itself, as well as between the system and the human motion. The spatial construction developed functions as an interface that questions the boundaries between body and space.

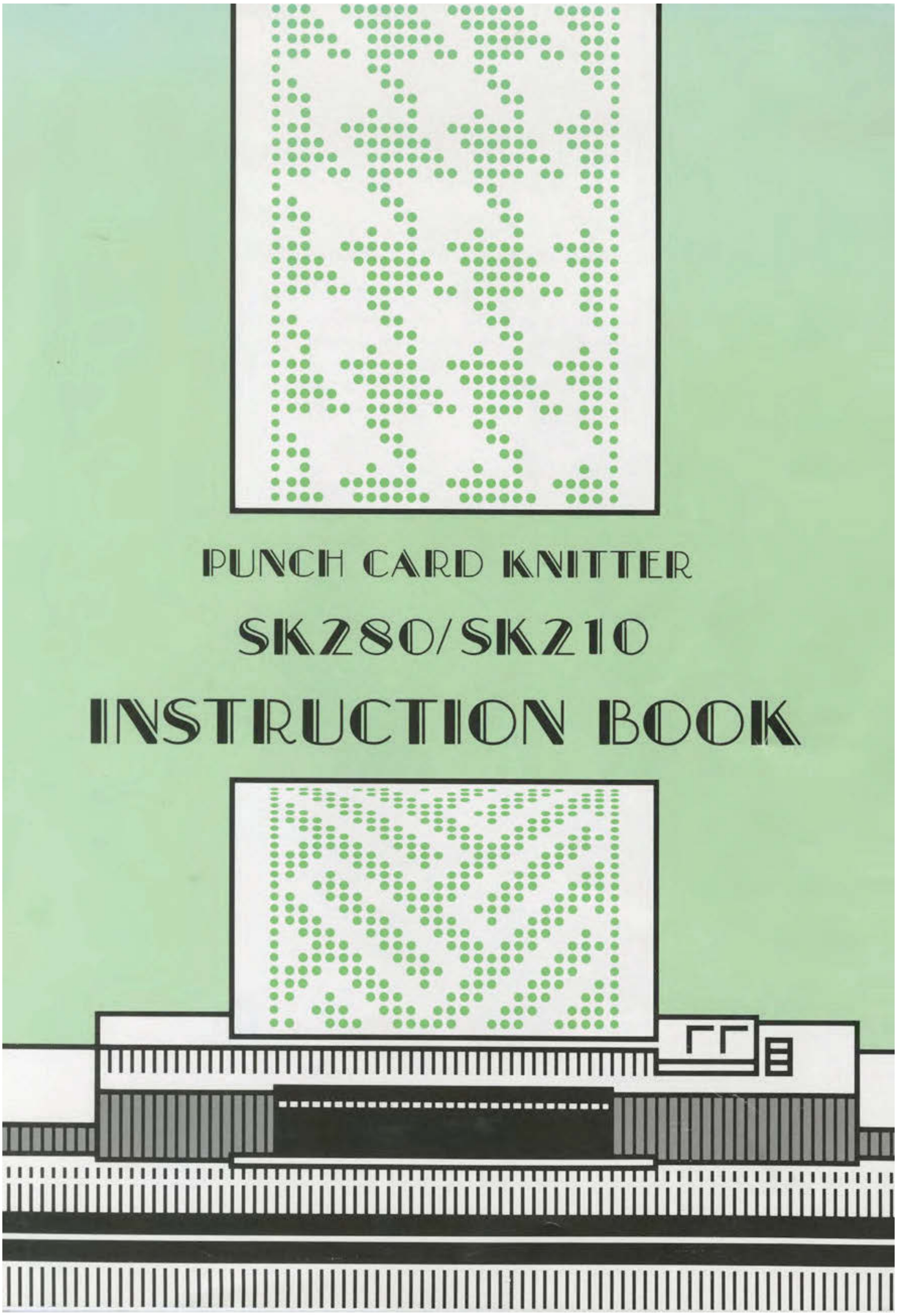
Space is defined as the interval between body and textiles. The interplay between body motion and the knitted structure generates space. Thus, the textiles functioned as a third skin that can be manipulated by the body. The outcome reflects the research methodology and experimentations with the material through body movements.

Potential for Further Research

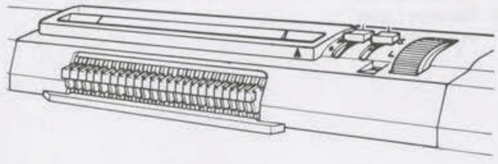
The manipulation of knitted textiles challenged properties to create a spatial topography of performance. This study focused on sensory experiences and the formation of space through body movements. This parameter led to the revelation of new formal qualities in knitted structures that forced us to reorganise our understandings and perceptions of their spatial potential. The project is the result of an experimental exploration of the tension between textile materiality and the human body. Multiple functions and textile applications could be derived from this exploration. However, the intention of this research was to create materials that reflected on the experimental creation of space through human motion. The concept of the study lies in stimulating the interaction between material, body and space. It aimed to create sensory experiences that question the perception of textiles by means of individual interpretation.

An experiment in itself, the research addressed the body in motion and its relationship with textiles in the formation of spatial organisation. The outcome creates a sensory experience felt through motion. The practical project is utilised as a tool to communicate a concept in relation to the spatial application of textiles, not to create an outcome on its own. However, the result presents potential for further research with different production processes of textiles, such as industrial fabrications. An extended exploration can challenge the scale of the knitted geometries and evolve into the creation of a spatial structure.

APPENDIX

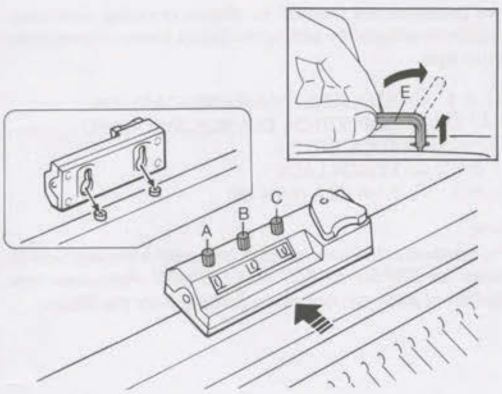


NAMES AND FUNCTIONS OF EACH PART



Pattern Panel

See page 18 for details.

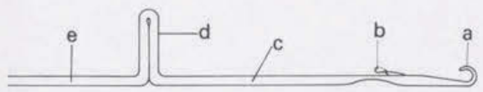


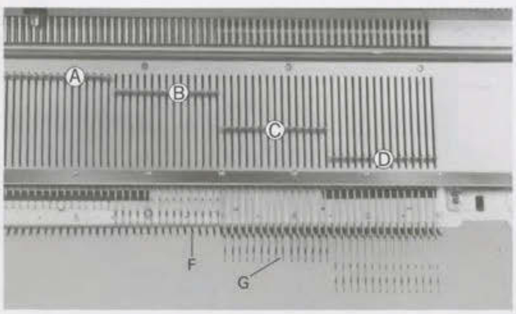
Row Counter

To reset number, turn the knurled knobs "A", "B" and "C" in either direction.

"E" — Row Counter Tripper at the right back of the Carriage operates the Row Counter.

To engage the Row Counter Tripper with the Row Counter, lift and point it towards the Row Counter. To disengage, lift and turn it to the side.





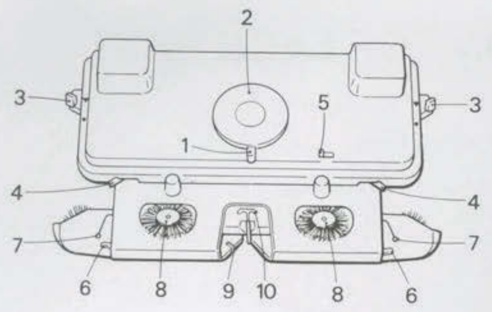
Needle Bed and Needle Positions

"F" — Sinker Post
"G"— Latch Needle
a — hook
b — latch
c — stem
d — butt
e — shank

On both ends of the Needle Bed are bracketed letters A, B, C and D. Align the needle butts inside the brackets.

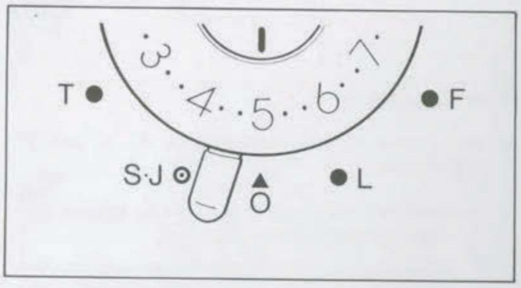
A — Needles do not knit.
B — Needles knit Stockinet and stitch patterns.
C — Needles knit Stockinet only.
D — Needles do not knit with Russel Levers at **I**.
Needles are knitted back to B position with Russel Levers at **II**.

The numbers 0 — 10 on the left and right side of centre(0) indicate number of needles.



Carriage and Arm

1. Cam Lever
2. Stitch Dial
3. Side Levers
4. Russel Levers
5. Release Lever
6. Weaving Knobs
7. Weaving Yarn Holders
8. Weaving Brushes
9. Yarn Cutter
10. Yarn Feeders



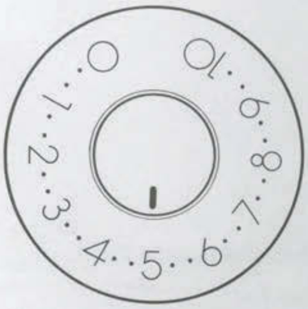
Cam Lever

Use this to select stitch type.

Five positions are marked as shown opposite, and each position is selected by setting the Cam Lever to the selected stitch type.

O (∧) — STOCKINET, WEAVING, CAST-ON
S.J (⊖) — SLIP STITCH, DOUBLE JACQUARD
T (⌒) — TUCK STITCH
L (∧) — PUNCH LACE
F (⩚) — FAIR ISLE (KNIT-IN)

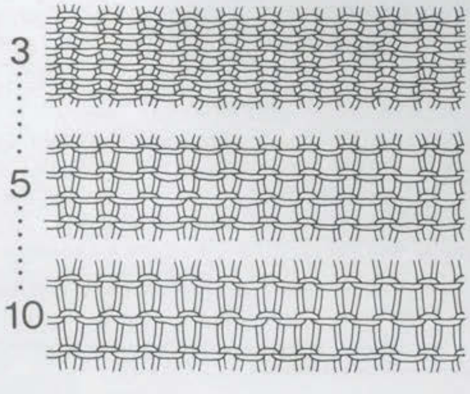
Note:
The symbols in the parentheses are used in the Instruction Books for SRP50, SRP60 and SRP60N. Remember the position of each symbol when knitting with the Ribber.



Stitch Dial

Use this to control the size of stitches.
Set the number to the **I** mark.

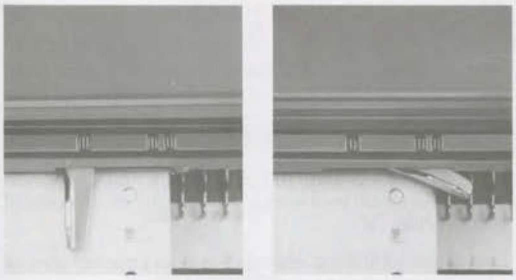
The higher the number on the Stitch Dial, the larger the stitch size (the fabric is loose). The lower the number, the smaller the stitch (the fabric is tight).



Side Levers

These control the needles in B position.

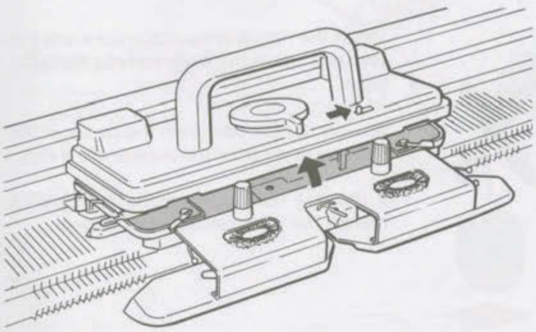
●.........Needles knit Stockinet only.
▼.........Set to this position to knit patterns using a Punch Card.



Russel Levers

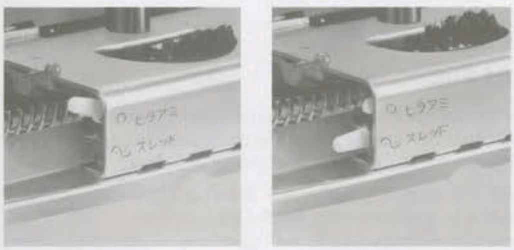
These control the needles in D position.

I..........Do not knit the needles in D position.
II.........Knit the needles in D position in Stockinet.



Release Lever

Using this lever, you can release the Carriage from a jam as well as move it across the Needle Bed without knitting.



Weaving Knobs

Move this knob to position the Weaving Brush.

O.........Set to this position except for weaving.
∾......Set to this position for cast-on and weaving.

To set the Weaving Knob to ∾, push it slightly forward; it will drop into position.

Yarn Cutter

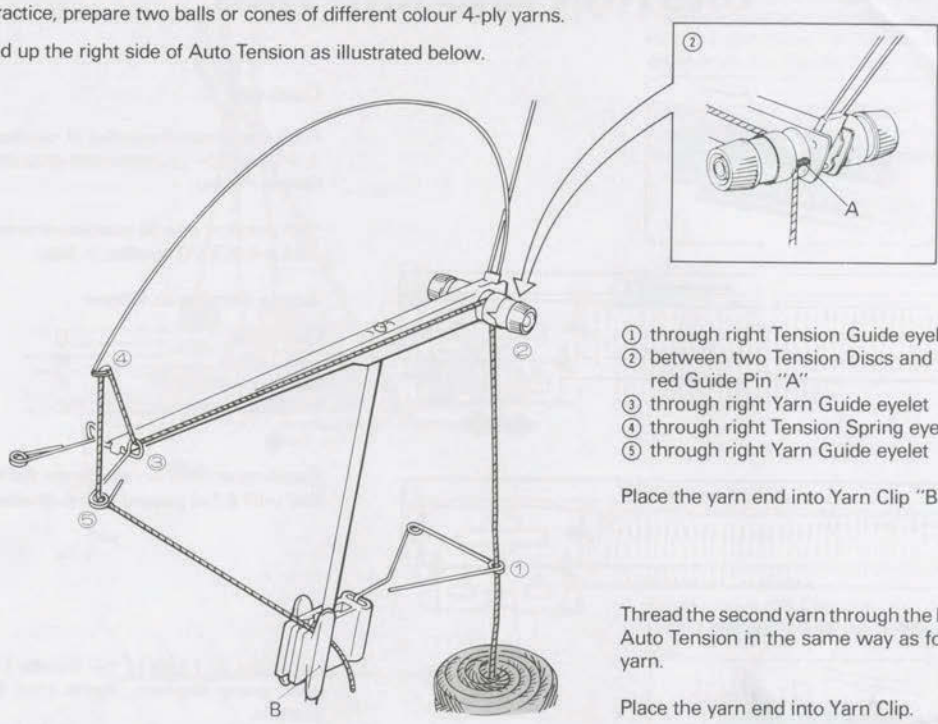
Use this to cut the knitting yarn.

Hold the yarn with both hands and press it against the cutter.

Threading the Yarns

For practice, prepare two balls or cones of different colour 4-ply yarns.

Thread up the right side of Auto Tension as illustrated below.

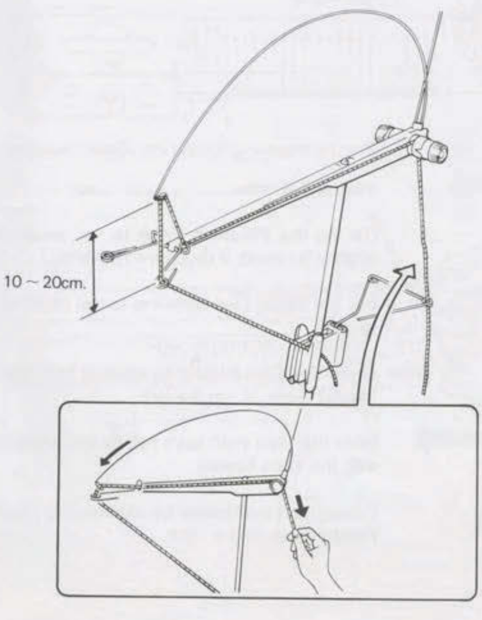


① through right Tension Guide eyelet
② between two Tension Discs and under the red Guide Pin "A"
③ through right Yarn Guide eyelet
④ through right Tension Spring eyelet
⑤ through right Yarn Guide eyelet

Place the yarn end into Yarn Clip "B".

Thread the second yarn through the left side of Auto Tension in the same way as for the first yarn.

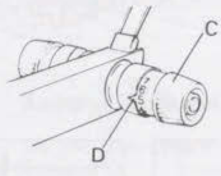
Place the yarn end into Yarn Clip.



Adjusting Tension Dial

Adjust the Tension Dial according to type of yarn by turning the Tension Dial "C" until required number corresponds to the < shape "D" using the following as a guide:

- Yarn comes out freely from the yarn ball.
- Distance between the Tension Spring and Yarn Guide...... 10 ~ 20cm. must be maintained.

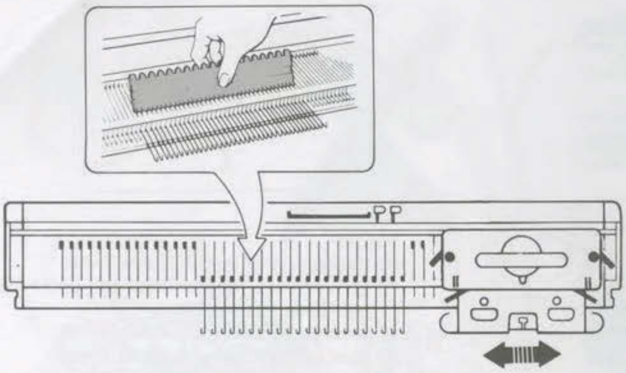


The higher the number, the tighter the tension, and the lower the number, the looser the tension.

It is advisable to free a length of the yarn from the ball before casting on.

CAST-ON AND KNITTING

Cast-on

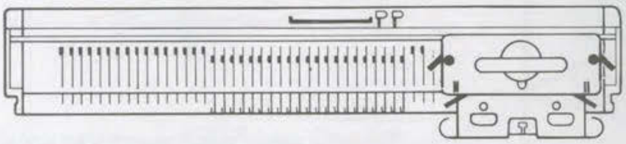


Push the required number of needles from A to D position using the straight side of the Needle Pusher.

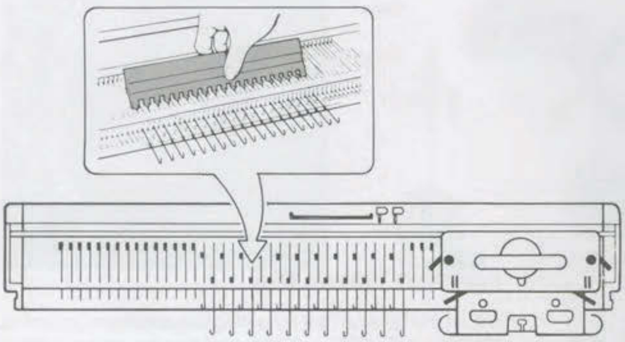
*For practice, use 35 needles on both sides of centre(0), 70 needles in total.

Set the Carriage as follows:

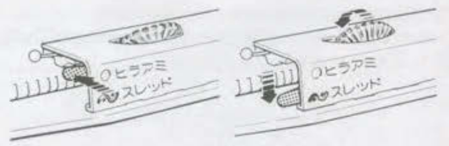
Cam Lever.............................. O
Side Levers............................ ●
Russel Levers......................... II
Weaving Knobs...................... O



Slowly move the Carriage across the Needle Bed until it has passed all the needles.



Using the 1/1 side of the Needle Pusher, push every alternate needle from B to D position.

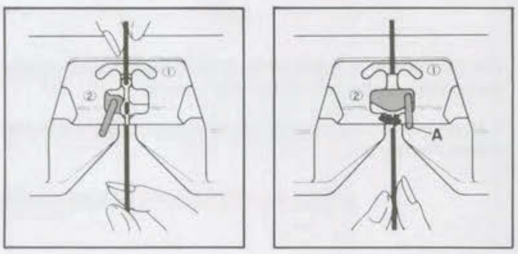


Set the Weaving Knobs into Down position.

Weaving Knobs...........................∾

(To set the Weaving Knob to ∾, push it slightly forward; it drops into position.)

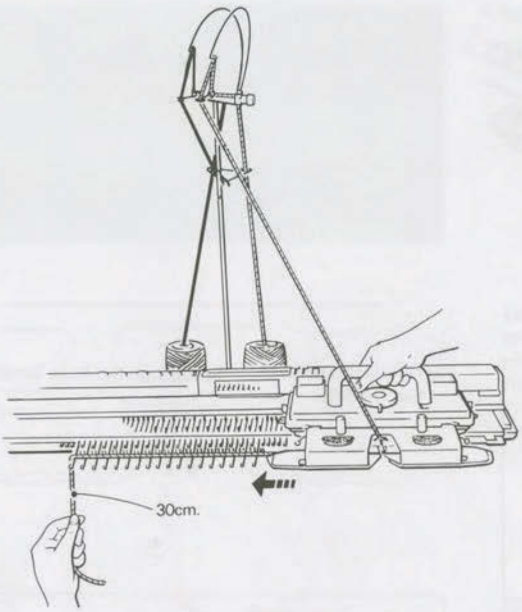
Set the Stitch Dial referring to the table on page 9.



Open the Yarn Feeder by moving the Yarn Feeder Gate "A" to the left.

Hold the yarn with both hands and slide it into the Yarn Feeder.

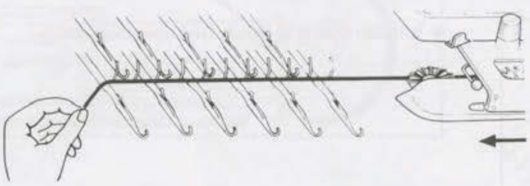
Close the Yarn Feeder by moving the Yarn Feeder Gate to the right.



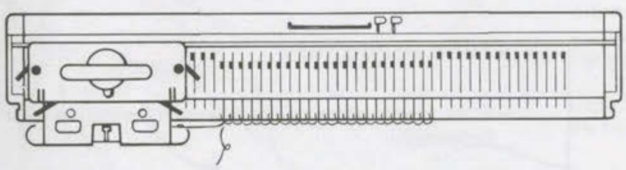
Pull the yarn end from underneath the Arm and lay it over all the needles in D position.

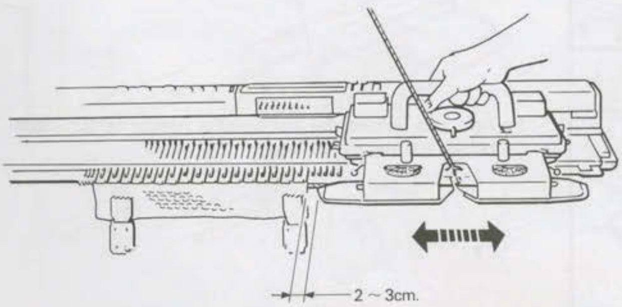
Hold the yarn loosely at the left about 30cm. down from the Needle Bed.

Eliminate slack yarn by pulling the yarn down at the back of the Yarn Rod until the Tension Spring is almost horizontal.



Slowly move the Carriage from right to left until it has passed all the needles to knit 1 row.





Ensure that the Arm has passed the last knitting needle by 2 ~ 3cm. before beginning the next row.

Continue to knit 2 ~ 3 rows.
Cast-on has been finished.

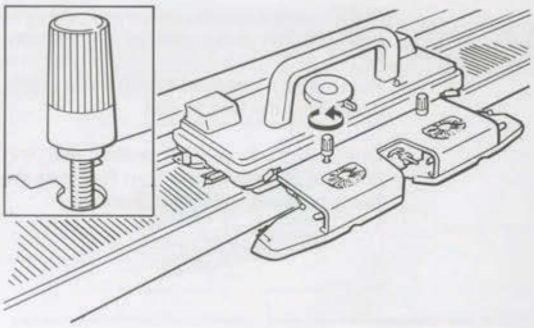
Knitting Stockinet

Set the Side Levers at ▼ and Weaving Knobs at O.

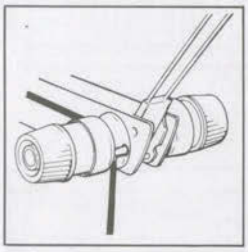
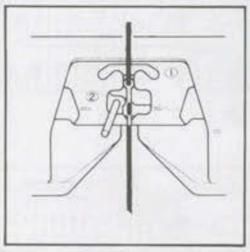
Knit 4 ~ 5 rows and hang the Claw Weights at both edges of the knitting.

Move the Carriage from side to side to knit Stockinet.

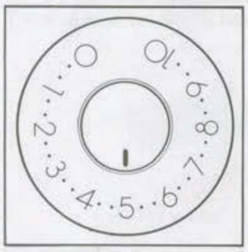
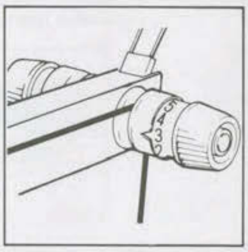
Check Points



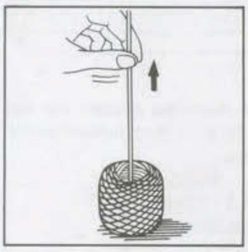
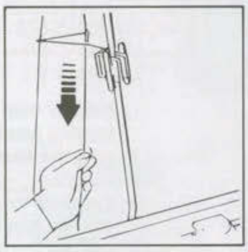
- Arm is attached to the Carriage correctly.

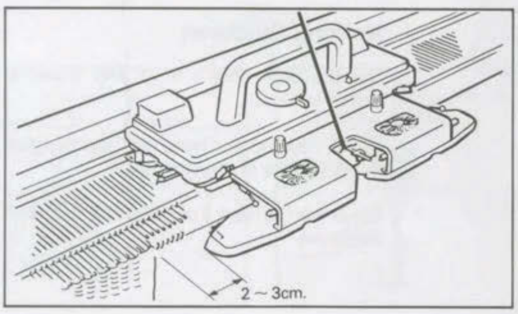
- Yarn is threaded correctly through the Auto Tension and Yarn Feeder.

- Tension Dial and Stitch Dial are set correctly.

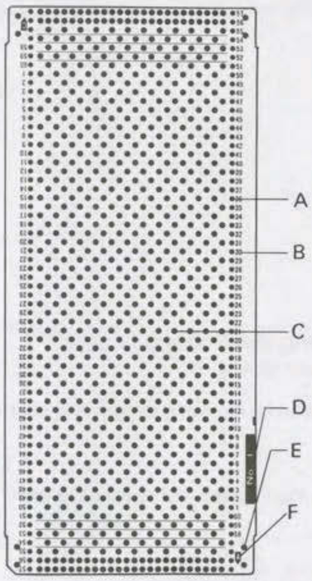



- Yarn is wound correctly.
- Slack yarn is eliminated and Tension Spring is almost horizontal.



- Arm has passed the last knitting needle by 2 ~ 3cm. before knitting the next row.

PATTERN KNITTING WITH MAIN CARRIAGE



Standard Punch Cards for Main Carriage

20 Punch Cards are supplied with the machine.

Names of each part of the Card:

A — Card Feeding Hole
B — Pattern Row Number
C — Punched Pattern Holes
D — Card Number
E — Card Snap Holes
F — Card Direction Mark (See page 18)

IMPORTANT!

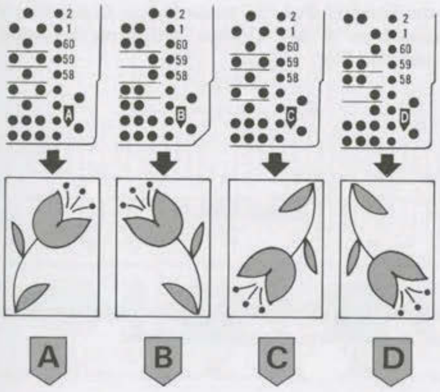
Keep the Cards away from heat and direct sunlight.
Do not fold or bend the Cards.

You can make your own patterns using optional blank cards and Handy Punch or Punching Machine.

With these 20 Punch Cards, the following patterns can be produced.

* Only for in colours

Card No.	Fair Isle (knit-in)	Tuck Stitch	Slip Stitch	Weaving	Punch Lace	Single Motif
No.1	○	○		○	○	
No.2	○		○	○	○	
No.3	○	○	○	○		
No.4	○	○	○	○		
No.5	○					○
No.6	○					○
No.7	○	○	○	○	○	
No.8	○	○	○	○		
No.9	○	○	○	○		
No.10	○	○	○			
No.11	○	○	○	○		
No.12	○	○	○			
No.13	○					
No.14	○		○	○	○	
No.15	○				○	
No.16	○				○	
No.17	○				○	
No.18	○				○	
No.19	○		*○			
No.20	○			○	○	

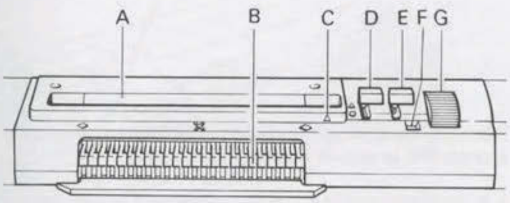


Direction of Punch Card

Each Punch Card has four different uses and is marked A, B, C and D.

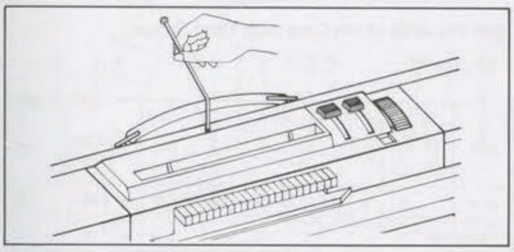
Direction "A" is basic pattern and directions B, C and D change the pattern as shown opposite.

Try to use the basic Direction "A" until you get to know the different effect well enough.



Pattern Panel

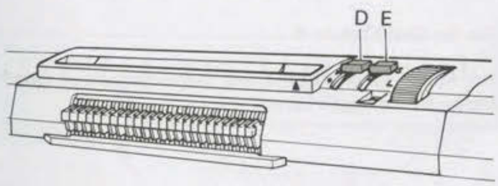
A — Card Insertion Slot
B — Touch Levers
C — Pattern Row Number Indicator
D — Stop Knob: Use this to control the card feed.
▼........... Feed Position
●........... Lock Position
E — L Knob: Use this to control the size of patterns.
S........... Standard Pattern Size
L........... Elongated Pattern Size
F — L Knob Indicator
G — Feeding Dial



Inserting Punch Card

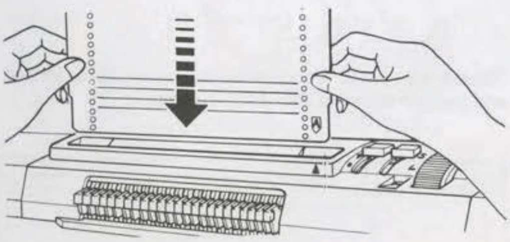
Prepare two Card Snaps and a Punch Card.

Remove the Card Guide from the Accessory Box and insert it vertically into the hole behind the Pattern Panel.

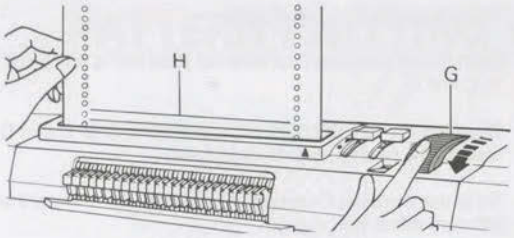


Set the Pattern Panel as follows:

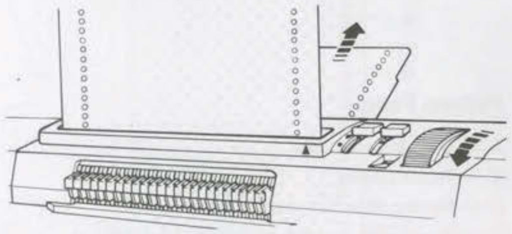
Stop Knob "D"........................ ▼
L Knob "E".............................. S



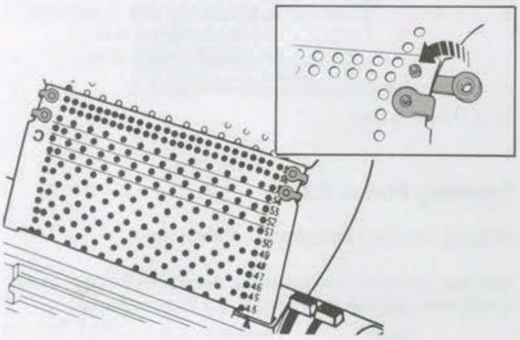
Hold the Punch Card straight with the Card Direction Mark at the right. Insert the Card into the Card Insertion Slot and push it down slightly.



Turn the Feeding Dial "G" towards you. Check that the horizontal lines "H" on the Punch Card are parallel with the Card Insertion Slot.



Continue turning the Feeding Dial until the card end comes out at the back, long enough to be folded.

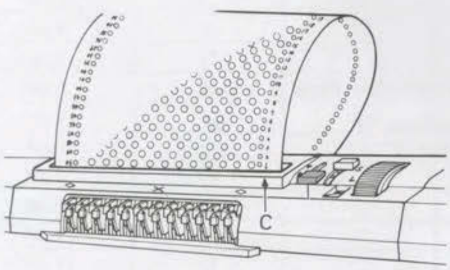


Place the back, longer end of the Card behind the front, shorter end as shown in diagram.

It is important that the Card is overlapped in this way to make the card feed smooth.

Line up the 2 holes on each side.

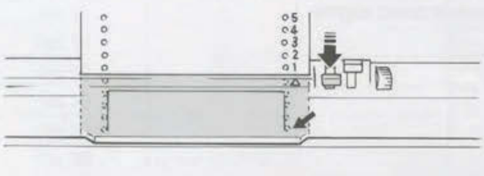
Join the ends of the Card with Card Snaps.



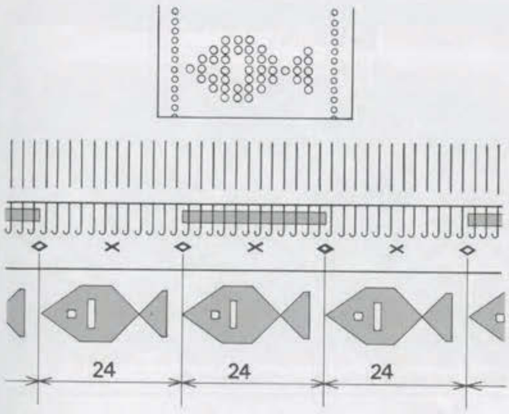
Turn the Feeding Dial until the row number "1" shows above the Pattern Row Number Indicator "C".

Set the Stop Knob to ●.

The Punch Card is locked and the initial pattern row is shown by the Touch Levers.



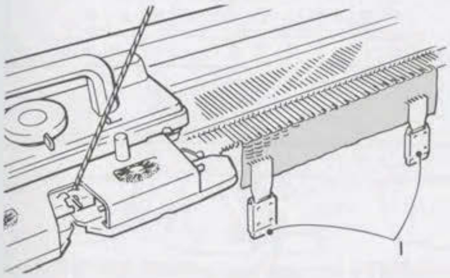
There is a 5-row difference between the row being knitted and the row showing above the indicator.



At the front of the Pattern Panel and on the front of the Needle Bed are markings ⨯ and ◇.

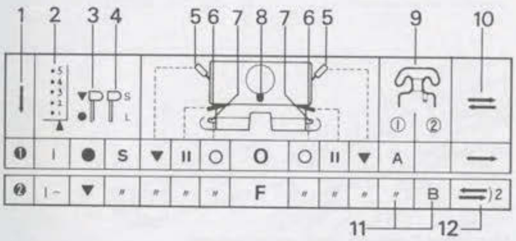
⨯ — indicates the centre of a pattern.
◇ — indicates width of a pattern.

Between two ◇ markings are 24 needles.
The centre of a pattern always comes at the centre(0).



Before starting pattern knitting, knit 7 ~ 8 rows in Stockinet with main yarn or work waste knitting and leave the Carriage at the left of the Needle Bed.

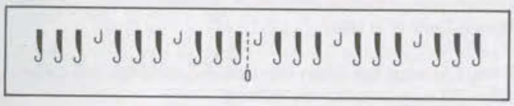
Hang the Claw Weights "I" at both edges of the knitting. (Move them up as knitting progresses.)

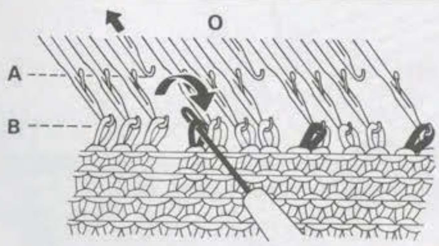


Reading Operation Table

1 — Order
2 — Pattern Row No.
3 — Stop Knob
4 — L Knob
5 — Side Levers
6 — Russel Levers
7 — Weaving Knobs
8 — Cam Lever
9 — Yarn Feeder ① and ②*
10 — Knitting Direction
11 — Yarn being used (A, B and C stand for different colours.)
12 — Number of rows to be knitted

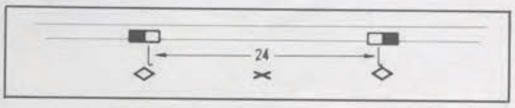
* Yarn Feeder ② column also means Weaving Yarn Holder or Plating Yarn Feeder.





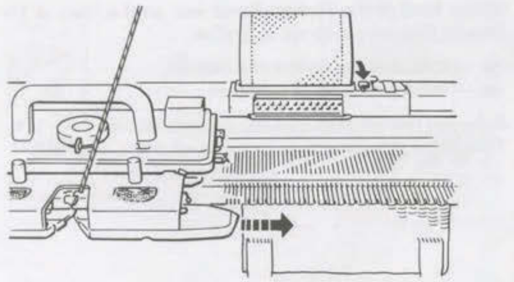
Needle arrangement

Transfer stitches on the needles to the adjacent needles and push empty needles back to A position.

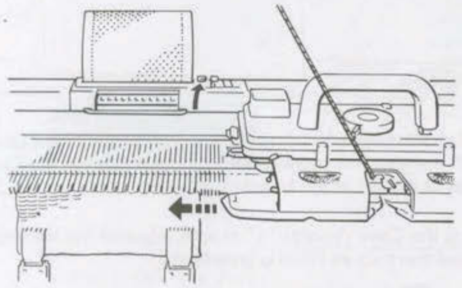


Point Cam M setting

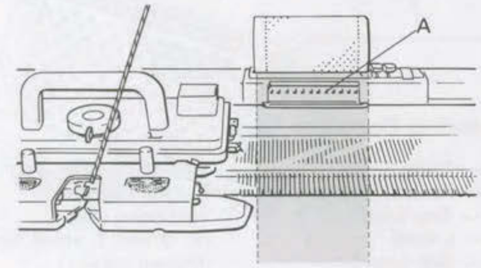
Place the Point Cams on the indicated positions of the Needle Bed.
Figure on the Operation Table shows the number of needles between Point Cams.



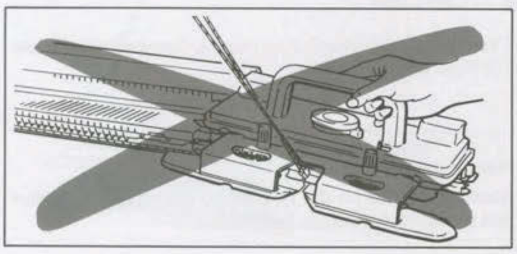
Column ❶ on the Operation Table is the row to memorize the 1st row of the pattern.



Start pattern knitting from Column ❷.



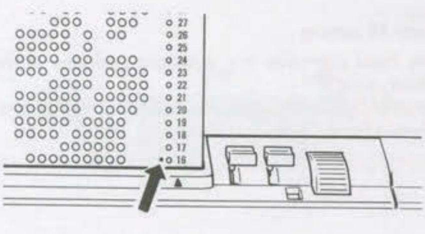
When moving the Carriage back and forth, ensure that the Carriage has completely passed all the Touch Levers "A".



Move the Carriage at an even speed.

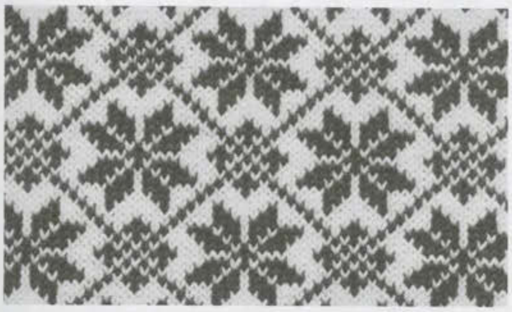
Do not remove the Carriage from the Needle Bed when the Punch Card is in use.

If the Carriage has been removed by accident, see pages 37 ~ 38 to memorize the pattern.



If the Pattern Row Number with ● mark shows above the indicator, change the yarn to contrast yarn.

FAIR ISLE (KNIT-IN)

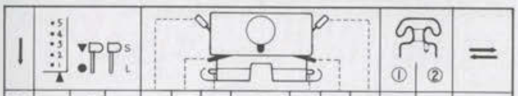


Two yarns of different colour are knitted simultaneously and form patterns on the fabric.

Perforated area of the Card knits the yarn in the Feeder ②, and non-perforated area knits the yarn in the Feeder ①, ground colour yarn.

The sample is knitted with Punch Card No.16-A.

Hang the Claw Weights at both edges of the knitting.

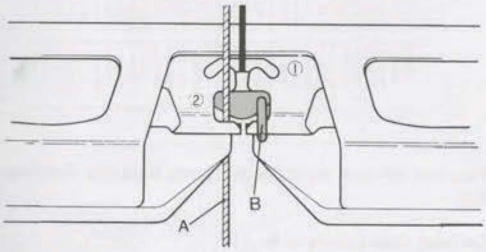


❶	I	●	S	▼	II	O	O	O	II	▼	A		—→
❷	I~	▼	〃	〃	〃	〃	F	〃	〃	〃	〃	B	⇌

Set the controls as required in ORDER ❶.

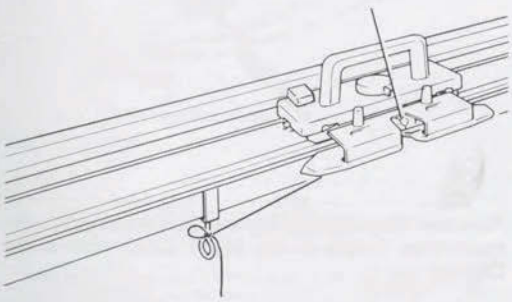
Knit 1 row from left to right.

Set the controls as required in ORDER ❷.



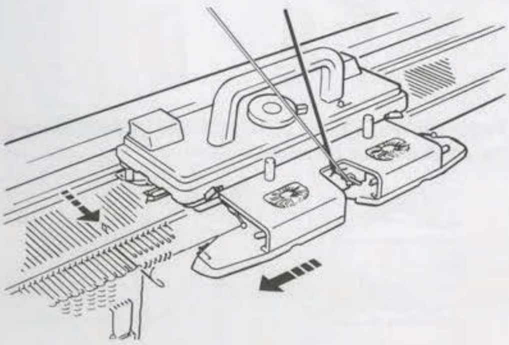
Remove the second yarn from the Yarn Clip and pull it down to the Carriage.

Insert the second yarn "A" into Yarn Feeder ②, left side of the Guide Pin "B".



Fasten the yarn end to the Clamp.

Eliminate slack yarn by pulling the yarn down at the back of the Yarn Rod.



If the end stitches do not knit properly, push end needle on the Carriage side to D (or C in partial knitting) position before knitting the next row.

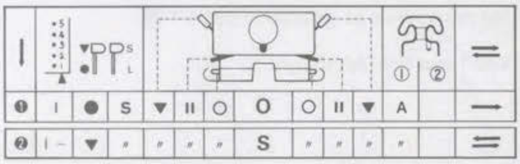
Knit the required number of rows as above.

SLIP STITCH

Perforated area of the Card knits Stockinet and non-perforated area leaves a float of yarn on the purl side of the fabric.

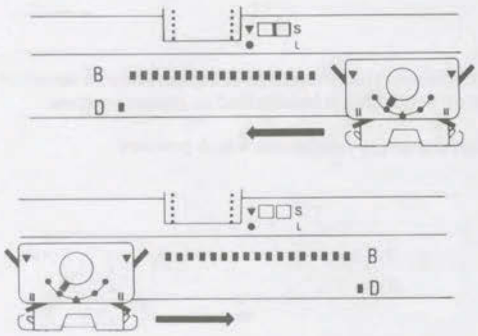
The sample is knitted with Punch Card No.14-A.

Hang the Claw Weights at both edges of the knitting.



Set the controls as required in ORDER ❶.

Knit 1 row from left to right.



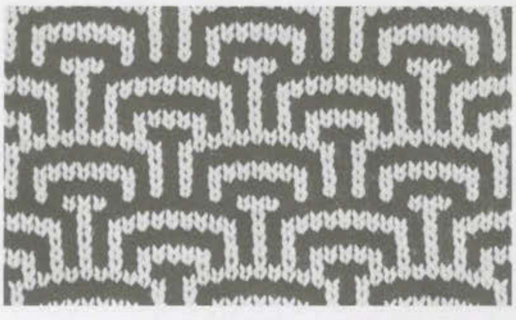
Set the controls as required in ORDER ❷.

Continue knitting.

Set the Stitch Dial 1 number higher than for Stockinet as the fabric of slip stitch pattern is tighter.

Push one end needle on the side opposite the Carriage to D (or C in partial knitting) position before knitting the next row.

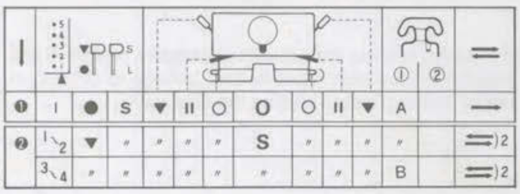
● Slip Stitch in Colours



Knit two or more different colour yarns alternately in slip stitch pattern.

The sample is knitted with Punch Card No.10-A.

Hang the Claw Weights at both edges of the knitting.



Set the controls as required in ORDER ❶.

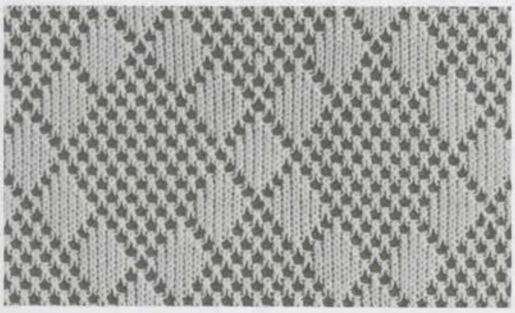
Knit 1 row from left to right.

Set the controls as required in ORDER ❷.

Knit following the Operation Table, changing yarns in the same way as for "Knitting Stripe Pattern" on pages 14 ~ 15.

Push one end needle on the side opposite the Carriage to D (or C in partial knitting) position before knitting the next row.

PUNCH LACE



Combinations of thick yarn and self-coloured very fine yarn produce a lace effect pattern.

Perforated area of the Card knits the yarn in the Feeder ② (thinner yarn) and non-perforated area knits both yarns together.

The sample is knitted with Punch Card No.18-A.

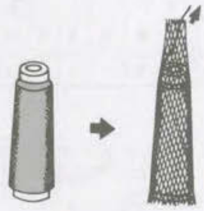
Hang the Claw Weights at both edges of the knitting.

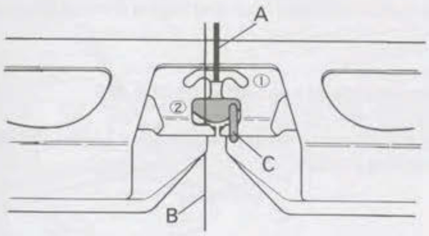
❶	I	●	S	▼	II	O	O	O	II	▼	A		→
❷	I~	▼	〃	〃	I	〃	L	〃	〃	〃	〃	B	⇌

Set the controls as required in ORDER ❶.

Knit 1 row from left to right.

Cover spool of nylon thread with Stop Net (option) or with a cut-piece of stocking.
Thread thinner yarn through the Auto Tension.





Set the controls as required in ORDER ❷.

Put thicker yarn "A" into Yarn Feeder ① and thinner yarn "B" into Yarn Feeder ② at the left side of Guide Pin "C".

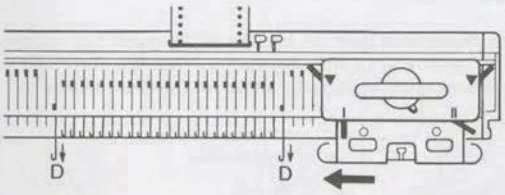
Bring the 1st and last needles to D position.

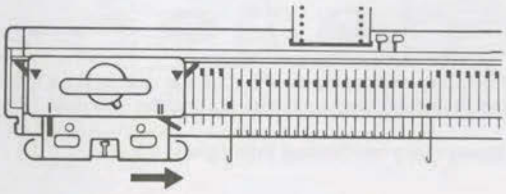
Knit from right to left.
The end needles will not knit.

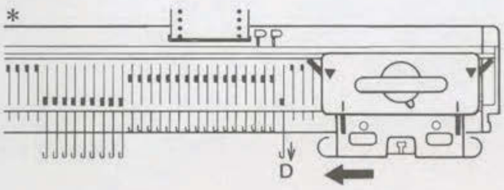
Knit from left to right.
The end needles will be knitted back to B position.

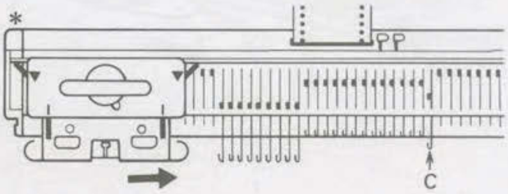
Knit the required number of rows, pushing the 1st and last needles to D position when the Carriage is at the right.

*(When partial knitting, set both Russel Levers to I, push one needle at opposite side of resting needles to D position to knit from right to left and push back the needle to C position to knit from left to right.)

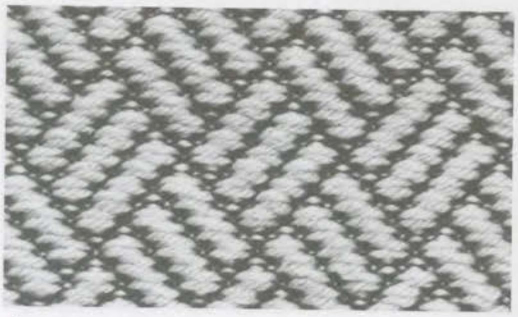








WEAVING



By passing fancy yarn or different materials (hereafter called weaving yarn) between the Stockinet stitches on purl side, a pattern is made on the surface of the fabric.

Perforated area of the Card passes the weaving yarn over the needles, and non-perforated area passes the weaving yarn under the needles.

The sample is knitted with Punch Card No.9-A.

Hang the Claw Weights at both edges of the knitting.

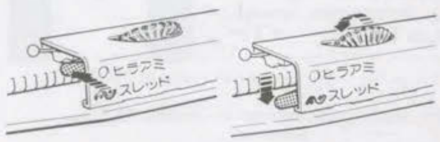
❶	I	●	S	▼	II	○	O	○	II	▼	A		→
❷	I ~	▼	〃	〃	〃	∾	〃	∾	〃	〃	〃	B	⇄

Set the controls as required in ORDER ❶.

Knit 1 row from left to right.

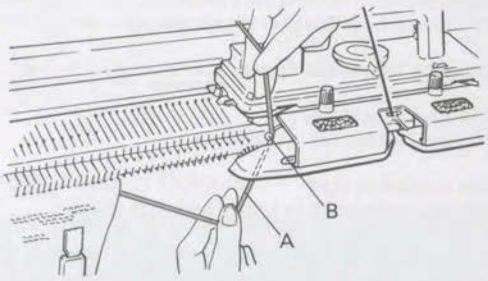
Thread the weaving yarn through the Auto Tension and pull it down to the Needle Bed.

Fasten the yarn end to the Clamp nearest the Carriage. Adjust the Stitch Dial. (1 number higher than for Stockinet)



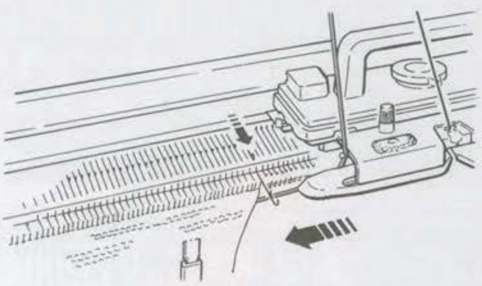
Set the controls as required in ORDER ❷.

To set the Weaving Knob to ∾, push it slightly forward; it drops into position.



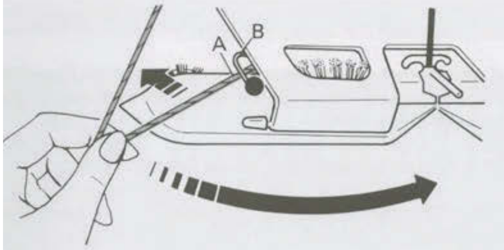
"＊" mark in the Yarn Feeder column means Weaving Yarn Holder.

Hook weaving yarn "A" into the left Weaving Yarn Holder "B". (Always put weaving yarn in Weaving Yarn Holder nearest to the knitting, as shown in the illustration left.)



Push one end needle on the Carriage side to D (or C in partial knitting) position before knitting the next row.

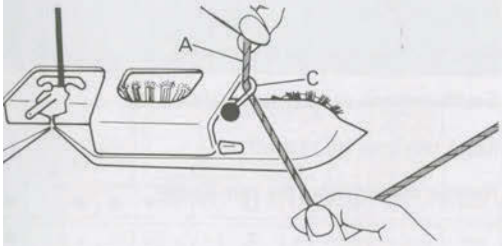
Slowly move the Carriage from right to left.



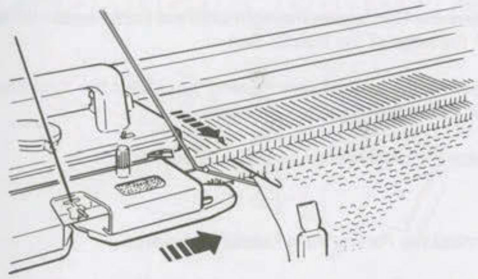
Remove weaving yarn "A" from the left Weaving Yarn Holder "B".

Bring the weaving yarn underneath the Arm and move it to the right side of the Carriage.

At this step, it may be necessary to push the Carriage slightly back in the original direction to free the weaving yarn from the brushes under the Arm.

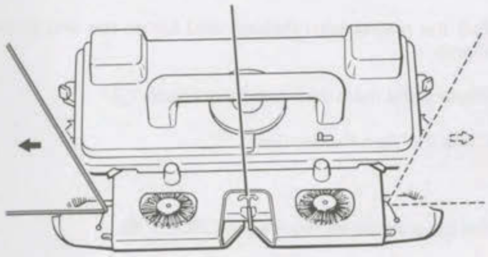


Hook the weaving yarn into the right Weaving Yarn Holder "C".



Push one end needle on the Carriage side to D (or C in partial knitting) position before knitting the next row.

Knit from left to right.



Knit the required number of rows always placing weaving yarn in the leading side of the Carriage.

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