PLEASE DO TOUCH

— an exploration of knitted tactile architecture

Hanna Lundberg - 2024

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Master thesis at Chalmers School of Architecture
Department of Architecture and Civil Engineering

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Thank you!

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Abstract

Please Do Touch aims to explore how haptic architecture can be created using the specific tactile qualities of knitted textile. Today, architecture can be seen as a visually driven practice, where touch rarely is central. By shifting the perspective to touch driven architecture, new aspects of architecture and space are explored, highlighting the potential of haptics in architecture as tools for creating human-centered spacial experiences with the potential of affecting mood and emotion. Knitted textiles present interesting tactile and spacial qualities that make them relevant for haptic exploration.

The research has mainly been done through research through design, consisting of material explorations and full-scale prototyping, in combination with literature studies, looking into concepts of textile architecture, tactile architecture, and their intersection. Material explorations were carried out on domestic knitting machines as well as by hand. Different fibers as well as knitting techniques were tested and evaluated using five different five-graded scales. For the architectural application, mounting techniques were also investigated. All this information was used to develop a full-scale prototype and an interior design proposal of a waiting room, chosen as a program which require both comfort and positive distraction.

Previous research suggests that smoother and softer textures are more pleasant than rough and hard ones. The results from the material explorations of this work suggests that more volume and a higher degree of responsiveness of the textile is more engaging and thus distracting. By using knitting techniques and fibers which generate high levels of softness, volume and responsiveness on both micro- and macro levels, the final design of this work has the potential of creating feelings of comfort and positive distraction within the context of the waiting room.

These findings suggests that there are important aspects of human emotion and perception of space that can be targeted by integrating intentional haptic stimulation into architecture, and shows that knitted textiles is a material which is well-suited for this purpose.

Key Words
tactile architecture, haptics, knitted architecture, textile, waiting room

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Chapter 1.

Introduction

Problem definition

Why touch?

Throughout history, dating back as far as to Aristotle, scholars have often ranked the senses based on their perceived importance. In this ranking process, the sense of touch has often been placed at the bottom, viewed as inferior to the other senses, especially compared to vision (Segal, 2020). This devaluation of touch still seems to linger within architecture today, where tactile stimulations is often reduced to tactile paving and braille lettering on navigation plans.

Touch is the first sense that is developed in the womb, and is fundamental for our understanding of the world around us. (Hertenstein, 2011). It has been found to be deeply important for many human functions, such as physical and cognitive development, as well as in the formation and upkeep of social relations (Essick et al., 2010). Haptic stimulation integrated into architecture has also been shown to affect the mood of its users positively (HKS Inc, 2019; Ahlquist, 2017). In light of this, tactility needs to be reexamined within the architectural context, ensuring important knowledge on possible well-being effects of our built environment is not missed.

Why knitted textiles?

Textile is not a new material to architecture, but the majority of fabrics used are woven. However, lately knitted textiles have gained more interest within the research field of architecture. This includes research into the structural qualities of knit textile, both as tensile structures for form work (Sahlin, 2023) and loose-fitted structures for wind-reduction and interaction (Hörteborn, 2023a). Additional research has looked into tensile knit textile as a backdrop for tactile interplay through combination with digital projection (Ahlquist, 2017). Within the growing field of computational design, knitted textile is also being explored, showing great potential for large-scale uses of the material in the future (Tamke et al., 2020; Ramsgaard Thomsen et al., 2023). This shows some of the possibilities presented by knitted architecture, and makes a case for the continued exploration and evaluation of knitted textiles within the architectural context.

Textiles also carry with them a tactile experience that today is familiar to most through clothing. Our tactile library is filled with impressions of how it feels against our skin, as draped fabrics. Schröpfer (2010) states that ”[t]extiles can carry in them memories and associations that appeal to the human sensibility offering softness, accessibility, and texture.” (p. 76). As such, textile present an excellent starting point for further explorations of tactility within the architectural framework.

Aim and research questions

The aim of this thesis is to bring focus to haptics within architecture by widening our understanding of how tactile elements of design affect human experience, and how this can be implemented, using knitted textile as the main material. It is also to create design that is allowed to be touched, and that is fun and interactable. As such, the work aims to investigate the following research questions:

1. How can tactile experiences affect our mood and how can this be combined with architectural programs?

2. What are the specific tactile qualities of knitted textile?

3. How can knitted tactile elements be combined with architecture in the program of the waiting room to create spaces that might encourage feelings of comfort and positive distraction?

Study objectives

These questions have motivated the following study objectives:

- Identifying architectural programs for which tactile stimulation is relevant in terms of enhancing desired moods, and applying the findings to one program for a design proposal.

- Creating a catalogue of knitted textile which explores their tactile qualities by specifically looking at the effect of fiber type and stitch technique in tactile experience.

- Identifying how knitted textiles can be used in an architectural setting by exploring both how it can be mounted as well as its ability to create and define space through a design proposal.

Relevance

Tactile aspects of architecture have been studied, but is often seen as subordinate to the visual expression, despite being central in human interaction with the built environment. Knitted textures have begun to be explored within architecture but have still scarcely been considered in a tactile light. This work aims to bridge and complement existing research within the separate fields with new knowledge on the overlapping topic of haptics and knitted textiles.

Scope

This work is positioned in the intersection between haptic, material, and architecture research. It investigates the tactility of knitted textile and how these can be integrated into architecture as spacial elements.

Although the main focus of the explorative work is on tactile experience, some focus is also placed on the interaction between the visual and the tactile.

Previous research on independent tactile stimulation (i.e. the interaction between a person and its environment rather than between two people) and its effects on mood are limited. The majority of studies found focus on the correlation between tactile stimulation and emotional reactions among neuro-diverse people, rather than looking at the entire population. As such, generalizations have been made in this thesis on the application of these findings for a broader user group.

Delimitations

The aim of this thesis is not to investigate tactility as an aid for the visually impaired, neuro-diverse individuals, nor children specifically, but rather to look broadly at the benefits of tactility for everyone. It is also not within the scope of this work to examine structural qualities on any level, fiber or knitted structure. Due to time limitations, questions of hygiene within waiting rooms will also not be addressed in the design proposal, but will be touched upon in the discussion.

Reading instructions

Chapter 1 presents the scope, aim and research questions which serve as the base for this work.

Chapter 2 presents existing knowledge within the fields of haptics, tactile architecture, textile and textile architecture with reference to projects and research projects, as well as possible combinations of tactile effects and spacial programs are presented.

Chapter 3 presents the general methodological framework which the thesis is situated in, as well as the specific methods used. It also presents materials and tools.

Chapter 4 presents parts of the knit explorations, which include both knitting techniques and mounting techniques. It also presents the main findings of these material explorations and a brief discussion.

Chapter 5 presents the production and result of a full-scale prototype based on the findings of chapter 2-4, as well as a brief discussion.

Chapter 6 presents how the findings from the full-scale prototype has been translated into a design proposal consisting of the interior of a waiting room.

Chapter 7 concludes the main findings of the work, and discusses these through personal reflection.

Chapter 2.

Background

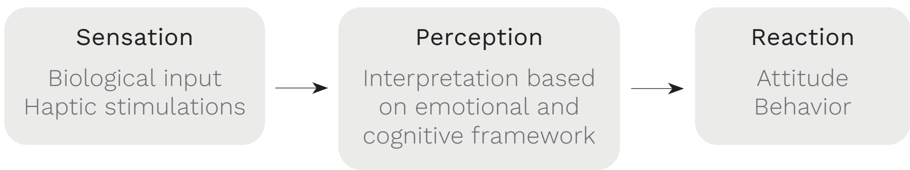
Background

Knitted, tactile architecture combines several fields of research: haptics, knitted textile and architecture. Haptic sensation is the sensation of touch, and much research has been done within the fields of physiology and psychology. Knitted textiles have previous uses within both the fashion industry and architecture, and some research also show its haptic potential.

Tactility

Haptic sensation and the perception of touch

Sensation is the first step in processing sensory information, and happens on a bio-chemical level (Krishna, 2021). For touch, this consists of haptic sensation, i.e. mechanical stimulation of the skin. When the skin surface is stimulated, neurons knowns as mechanoreceptors in the skin transforms this input from mechanical motion to electrical impulse. This makes them readable for the central nervous system (i.e. the brain and the spinal cord) (Jenkins & Lumpkin, 2017). Sensation is followed by perception, where the bio-chemical reaction is interpreted by the brain. This creates an "awareness or understanding of sensory information" (Krishna, 2021, p. 334). This understanding might differ from the reality of the bio-chemical input, which is what happens in the case of visual illusions. The trick-of-the-eye experience is a result of a discrepancy between what is actually in front of us, and expectations we have based on previous experience. Perception causes both emotional and cognitive responses which will affect both attitudes and behaviors. This chain of information processing make up the framework of tactile perception (fig 2.1)



2.1 Conceptual framework of tactile perception as described by Krishna (2021)

Much research done within the field of touch perception focuses on investigating individual materials on a micro-level, generally as flat surfaces, rather than investigating the effects of volume differences across a materially uniform surface.

Hollins and colleagues (1994) found that common descriptors for surface textures included 'smooth', 'rough', 'hard' and 'soft'. Even when given the opportunity to also evaluate materials on a 'flat-bumpy' scale (meant to encourage macro-level evaluation), participants used these fairly interchangeably with the 'smooth-rough' scale. This unfortunately gives little insight into the effects of macro-textures on texture perception.

The effects of the 'smooth-rough' and 'soft-hard' spectrum of experience has also been suggested to correspond to different perceptions of pleasantness. 'Smooth' and 'soft' generally correspond to pleasant perception, whereas 'rough' and 'hard' does the opposite (Etzi et al., 2014; Iosifyan & Korolkova, 2019). Level of roughness, and thus unpleasantness, has also been found to be amplified with increased applied pressure onto harder materials (Essick et al., 2010; Lederman, 1974).

Both passive (Essick et al., 2010; Hollins et al., 1994) and active (Iosifyan & Korolkova, 2019; Lederman, 1974) interaction methods of generating haptic stimulation have been explored. Passive interaction has been done by letting the texture stimulus be delivered by an instructor, whereas active stimulation consisted of allowing participants to interact on their own with the presented textures. It is worth noting possible limitations in both approaches. For passive interaction, questions surrounding the true-to-lifeness of the situation can be asked, suggesting that in a real-life-situation active interaction is much more likely, questioning how relevant the results of passive investigations are. For active interaction, limitations include difficulties in keeping enough parameters, including force and velocity of application, stable to ensure statistically significant results. Only the study by Etzi et al. (2014) investigates both methods, and their findings suggest that active interaction may increase experienced unpleasantness for materials which are generally considered unpleasant. In further design investigations this is important to note as architecture is a field which invites active interaction,

Haptic design and architecture

Much of previous research on haptic design within architecture is centered around tactility as a mean of distraction and stimulation for neuro-diverse individuals, such as those with autism spectrum disorder (ASD) and attention deficit hyperactive disorder (ADHD). For these individuals, abnormal sensory processing is common, meaning individuals can show higher or lower sensory seeking traits than neuro-typical individuals. Often, this is shown through sensitivity towards textures (low sensory seeking) or forceful tactile interaction (high sensory seeking). Tactile aids, both in smaller scale toys and in larger spacial installments have been proven useful in regulating and safely stimulating these behaviors (HKS Inc, 2019; Ahlquist, 2017; Danish 2023).

The research project Sensory Wellbeing Hub developed by architecture firm HKS Inc (2019) offers sensory stimulation through the use of tactile, visual, kinetic and acoustic sensory affordances[1]. Multiple installations together create a space for sensory distraction for students both with and without ASD, including elements such as

[1]Design features which aid sensing (e.g. touching, seeing, hearing) (Hartson & Pyla, 2018, Chapter 30)

a fidget wall, a spin chair, a bean bag with weighted blankets, and a tensile cocoon made from textile materials with sound dampening walls. The research found “improvement in sustained focus, happiness and engagement when in the Hub compared to before the visit” (p. 21). It also found that some of the most used elements of the installment were the cocoon and the weighted blankets and bean bags, which both offer near full body compression, as well as the fidget wall. This was true in all cases for individuals with ASD, and in many cases for those without as well. It was also found that different types of stimuli were preferred both comparing ASD vs non-ASD individuals, as well as comparing high sensory vs low sensory seeking individuals with ASD. The authors thus suggest future design development to include a variation in intensity of sensory stimulation, to offer sound-absorbtion when possible to lower noise levels, and encourage use of tactile and compression generating elements (HKS Inc, 2019). As these findings seem to hold true not only for individuals with ASD, it can be assumed that tactile and compressive stimulation can be appreciated and beneficial for all, not just those with ASD.

Also working ASD individuals, Sean Ahlquist (2017) combines textile structures with digital projection to create elements which invite for deep pressure sensation play for children with ASD. His research also take into consideration the non-verbal trait sometimes displayed in individuals with ASD, and emphasizes the use of these playscapes as meeting places for these children by allowing them other means of interaction and communication than speech. This shows that the possible uses for tactile stimulation runs deeper than simple sensory stimulation, and can actually function as a social connection tool between people.

Although much of the focus of these two projects related to sensory issues connected to ASD, arguing that these positive effects could hold true for a wider target group is within reason, which is also supported by the findings of the Sensory Wellbeing Hub project. This also gives support to investigating the general effects of haptic stimulation further within the field of architecture.

Tactile architecture and spacial programs

As tactile stimulation seem to have both a calming and uplifting effect for all individuals (HKS Inc, 2019), combining it with the right architectural program could help create environments where the architecture helps to encourage and regulate emotions. As seen in mentioned case studies, these programs could include schools, both as break rooms and in auditoriums, playscapes, and public spaces. These are spaces generating either calmness or high energy, and does so using different strategies.

Highly interactive elements of the designs which require moving the entire body (e.g. play), such as the playscapes of Sean Ahlquist (2017) and the more active tactile elements of the Sensory Wellbeing Hub (HKS Inc, 2019) create high energy emotions. In contrast, elements which only require minor movements, such as only using the hands (e.g. fidgeting), or being “passively” compressed, as is the case for other parts of the Sensory Wellbeing Hub, contribute with calmness. It also seems like the combination of tactile input with other sensory experiences can help highlight these effects. For example, the lowered level of auditive input in the cocoon of the Sensory Wellbeing Hub, in combination with the tactile sense compression increased calmness (HKS Inc, 2019).

To further investigate the opportunities for haptic design within architecture, these research findings can be used as a base for suggesting appropriate combinations of programs and stimulations, see table 2.1.

	Emotional and cognitive effects of haptic stimulation	Suitable architectural programs
Low energy	High focus Positive distraction Breaking off previous activity Calmness Relaxation	Care facilities Waiting rooms Auditoriums Classrooms Office spaces Break spaces
High energy	Happiness Positive distraction Breaking off previous activity Social connection	Break spaces Playgrounds Public spaces

Table 2.1 Possible combinations of emotional and cognitive responses to haptic stimulation with spacial programs

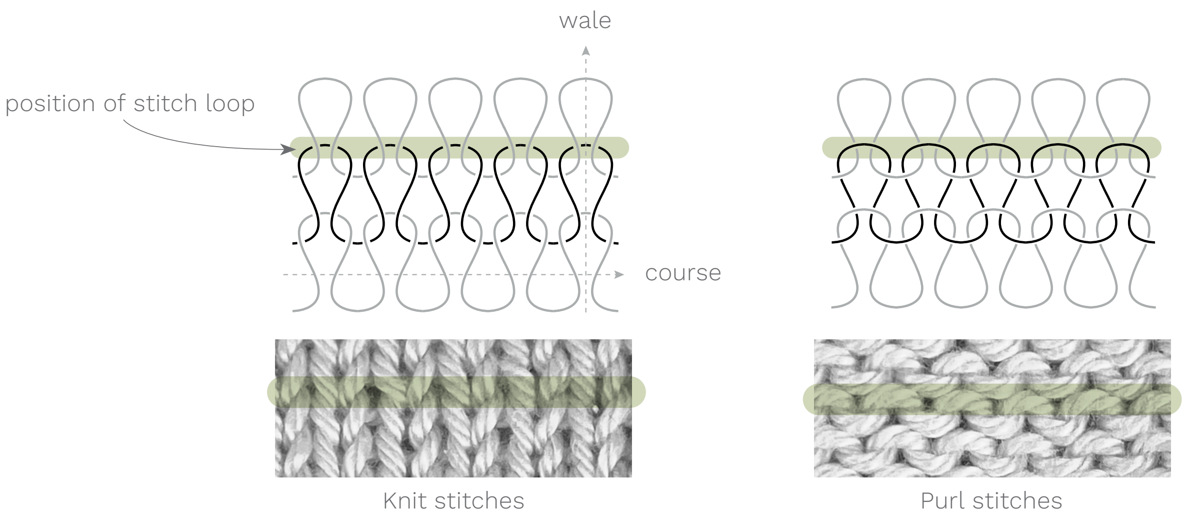
Textile

Textile can be defined as "any filament, fibre, or yarn that can be made into fabric or cloth, and the resulting material itself" (Abrahart & Whewell, 2024, para. 1). The production methods include weaving, knitting, felting and tufting, and are executed using an array of fiber materials. Today, common fibers include both natural fibers such as cotton, wool and flax, as well as man-made fibers such as polyester, acrylic, and fiber glass. These are widely used within the fashion industry, but are also increasingly utilized in other contexts, such as architecture.

The principles of knitting

Knitting and weaving are both basic techniques for producing textile fabrics. Where weaving consists of multiple, non continuous strands being joined together, knitting can consist of only one strand being looped together, essentially into one big knot (weft-knitting). This means a thread of yarn being used in knitting can be unraveled to be completely reused again.

Knitting is at its smallest constituent a stitch, where a stitch is essentially a loop on the continuous thread. Depneding on the position of this loop in relation to its surrounding loops, it is either called a knit or a purl stitch (fig 2.2). A knit stitch is when the top of the loop in a row is resting behind the base of the loops in the row above it. A purl stitch is the opposite, when the top of the loop rests in front of the base of the loops. This means that one side of a standard stitch will always be a knit stitch, and one side will always be a purl stitch. Altering how these stitches sit in relation to the front and back of the fabric, or the process through which they are created (e.g. twisted, increase, decrease), is what generates any built-in shape or texture that the resulting textile might have. In knit textiles, a horizontal row is known as a course, and a vertical column is known as a wale. The chosen sequence of stitches along these can also help create a textured effect.



2.2 Principles of knit and purl stitches

Textile in architecture

Semper (1989) argues that the historical use of textiles has had a great impact on the shape and development of architectural forms. The earliest space divider was a woven structure at its core, the wickerwork. "Wickerwork [...] retained the full importance of its earlier meaning, actually or ideally, when later the light mat walls were transformed into clay tile, brick, or stone walls. Wickerwork was the essence of the wall." (pp. 103-104) Similarly, Faegre (1979) argues that tent constructions are the truest form of architecture, also because the meaning of the word architect stems from "the Greek archi, 'the one who directs' and tectos, the 'weaving.'" (p. 1) As such, textile methods of production are at the core of our understanding of what a wall, and by extension architecture, is.

Much of textile used within architecture today consists of woven, tensile structures, much like the original wickerwork. As textile is lightweight, it can easily span across distances where other materials might struggle, whilst also adapting to complex geometry. This can be seen in the roof and facade structures of projects such as the O2 Arena in London, and the Zenith music hall in Strasbourg. On smaller scales, textile is often used as solar shades and curtains, as well as in furniture.

Knitted textile in architecture

Although not as common as woven textiles, knitted textile has also been explored within architecture.

Sahlin (2023) explores ornamental knitting as casting frameworks for concrete, generating decorative drop formations where the knitted structure is less dense or contains lace holes.

Hörteborn (2023a) explores the kinetic qualities of knitted architecture when combined with wind. She looked at how knitted textiles behave both as wind reducing barriers and as aesthetic installations within architecture, and translated these findings into architectural installations (fig. 2.5).

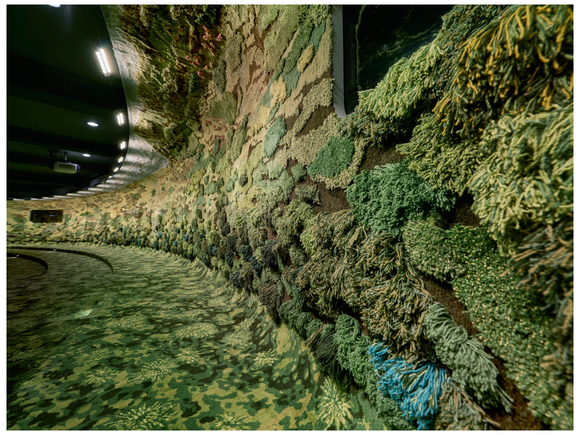
Knitted textile has also been combined with computational design and CNC manufacturing, creating greater possibilities of utilizing the possibility of shaping the fabric in 3D space already at the onset of production (Tamke et al., 2020). This combination also offers faster production at a larger scale, which has made it a common tool within textile architecture.

Projects which utilize CNC knitting for larger structures include 'Lumen' by Sabin et al. (2018) and 'Emergence of the complete' by Research Studio for Knit and Architecture (2023a). 'Lumen', as seen in fig 2.3, shows how knitted structures can be used to create temporary spacial installations that also invite interaction. A knitted honeycomb patterned canopy protects visitors from the summer heat. Some of the openings in the canopy are attached to tubes of knitted fabric, reaching almost all the way down to the ground. These tubes are intended for interaction and play, to touch and enter inside of. 'Emergence of the complete' (fig 2.4) explores how knitted textile can be used as space-generating elements. By combining opaque knit with semi-transparent

2.3

2.4

2.5



2.6

surfaces made up of strands of yarn, semi-private spaces are created.

Overall, knitted structures present an opportunity to develop environments that provide tactile stimuli. It can be through the structure of the knit fabric itself, or the way through which the fabric is installed onto other structures. Knitted textures also hold the ability to be manipulated in and of themselves, as compared to for example concrete which is dependent on the form into which it is cast to retain any surface at all.

The haptics of textile architecture

Textile in architecture is mostly used in hard-to-reach areas, such as ceiling structures, or consist of fibers that are less pleasant to touch, such as fiber-glass.

However, there are exceptions. Woven fabrics are used for curtains or room dividers, which are often maneuvered by hand, creating tactile connection between the elements and its users. It is also common to use woven carpets as flooring, and many furniture use textile for added comfort. In addition, textile in different shapes and forms are used for its acoustic qualities, such as in MVRDV's (2017) project Jut Group Lecture Hall, where a tufted art installation is used to clad the walls, bringing opportunities for both acoustic and tactile qualities (fig 2.6).

2.3 Lumen by Jenny Sabin Studio for The Museum of Modern Art and MoMA PS1's Young Architects Program 2017, on view at MoMA PS1 from June 29 to September 4, 2017. Images courtesy MoMA PS1. (Winter, 2017). Reprinted with permission.

2.4 'Emergence of the complete' by Research Studio for Knit and Architecture (2023b). Studio work. Reprinted with permission.

2.5 Drop stitch prototype from 'Knitted architecture and wind' by Erica Hörteborn (2023b; 2023c). Cropped and reprinted with permission.

2.6 Jut Group Lecture Hall by MVRDV. Photos by Jut Group. (Jut Group, 2017). Reprinted with permission.

Chapter 3.

Method

Research positioning

Richard Foqué (2010) argues that artistic and scientific research differ on many points. Scientific research consists of trying to prove (or disprove) one given hypothesis, making it an "ongoing process, where definite results are never obtained, but our knowledge about the world nonetheless increases permanently through a constant process of conjectures, refutations, and verifications." (p. 33). In contrast, Foqué goes on to say that:

> Artistic inquiry deals with immeasurable parameters and intuitively-made decisions and by its own nature cannot be subject to verification or falsification. This is not because art does not produce hypotheses about the world. In fact, each work of art is a hypothesis *per se*, but because these hypotheses can never be true or false, right or wrong, they have to keep their status of hypothesis forever. [...] [T]hey are not guesses as to how the world works, but instead suggestions from the artist to the viewer of how the world might be perceived. In that sense the terms 'right' or 'wrong' are meaningless." (p. 34)

The field of architecture sits between science and art, as a part of design research. It, like science, strives for finding a solution to a known problem, but through similar processes used in art. Where science looks at how things are objectively, and art at the individual perception of things, design looks at how things *could be*. Foqué argues that testing in design thus serves a purpose (as compared to art where it is pointless), but the tools used are different. Instead of testing for the true or false, the objective, and the universal, design research aims at finding a most desirable option. This is done through perspectives which are contextual and subjective, but not necessarily individual.

This thesis work views design is not as an area of numerical fact, but rather that of subjective human experience, in line with the reasonings of Foqué. As the aim of the work is to investigate human perception, making it inherently contextual, it makes little sense to attempt to align it with scientific rules of falsifiability and replicability. Instead, a qualitative research approach, as defined by Creswell and Creswell (2018), is fitting as it allows for explorations of personal experience.

Research through design

The specific design related framework for this research has been *research through design* (RTD), a common framework for research within the architectural field. However, despite this there is no one definition of the term, with different scholars using varying, albeit similar explanations of the term. In addition, similar terms, such as *research by design* and *practice-based research* are used fairly interchangeably with RTD (Hörteborn, 2023a). Hanington and Martin (2012) defines RTD as "[recognizing] the design process as a legitimate research activity, examining the tools and processes of design thinking and making within the design project, bridging theory and building knowledge to enhance design practices" (p. 146). In alignment with this definition, this thesis recognizes the design process as a generator of new knowledge, and the design and evaluation of material samples and design prototypes are central to the findings of this work. In addition, design and architectural practice is often an iterative process, where the needs of the end-user might change quickly. As such, user-input is also an important part of the process, making early design proposals one step of the design process rather than a final product. The findings presented here should be viewed in this light, as a foundation for further design proposals and research to be built on.

Methods

Literature studies

Books, reports and online resources have been studied to form an understanding of the precedents within the fields of tactility, tactile architecture, textile and textile architecture. These consist of works within the fields of architecture, design and psychology which look into the prevalence and effects of tactile stimuli and textile space. This information has then served as a base for identifying relevant architectural programs for tactile stimulation, as well as how textile can be integrated into architecture.

Knitted textile swatches

For the early stages of this work, an open-ended explorative phase was conducted during which knitted swatches were created. These were done so freely, aiming to explore and investigate tactile sensation and possibilities, rather than answer a given hypothesis. After being knitted, they were evaluated for further iterations.

The evaluation consisted of finding swatches with the greatest potential of fulfilling requirements for applied design proposal. This was done by active interaction with each swatch. Each swatch was manipulated between the fingers by being held freely in the air (no backing material) as well as without any mounting (samples was kept lose rather than tensile). The swatches were explored and rated on five different five-value scales of evaluation (fig 3.1). All swatches were evaluated comparatively to each other, meaning a value of completely smooth is smooth in relation to other swatches of this study, rather than a 'perfect' smooth surface. Stockinette stitch (plain knit) was investigated as a base for understanding the effects of different materials on the basic tactile input (see *Appendix A*), whereas other knitting techniques were evaluated for their combined effect of material and technique (see *Appendix B*).

Critical evaluation scale

These scales were chosen as indicators of texture pleasantness, touch-encouragement, visual interest, and practical feasibility.

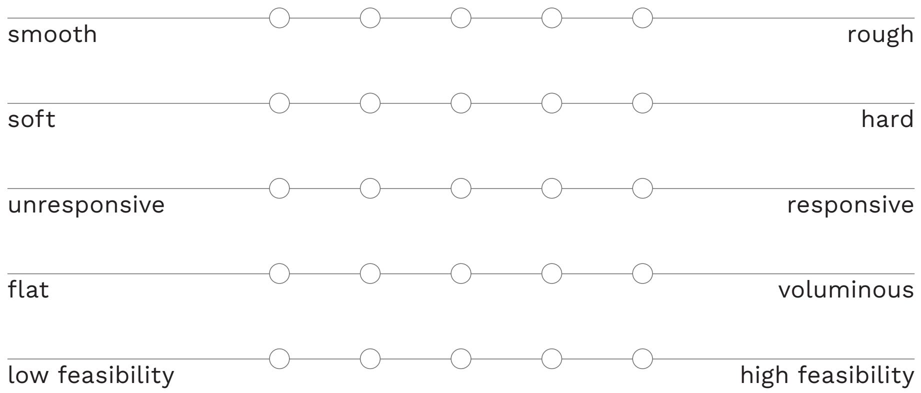
Smooth - rough
Evaluates the uniformity and perceived friction of the texture. Higher uniformity and less friction gives smoothness, higher irregularity and higher friction gives roughness.

Soft - hard
Evaluates the level of compression possible in a texture. High ease of compression gives softness, low level of ease gives hardness.

Unresponsive - responsive
Evaluates the extent to which the texture can be manipulated by interaction, such as by pushing parts of the texture back and forth. Textures which cannot be manipulated are unresponsive, textures that can be manipulated are responsive.

Flat - voluminous
Evaluates the height or protrusion of a texture from the base level. High protrusion gives volume, low protrusion gives flatness.

Low feasibility - high feasibility
Evaluates the feasibility of replication on a larger scale using a domestic knitting machine, as needed for the creation of the 1:1 scale prototype for this thesis.



3.1 Scales of evaluation for sample textures

Full-scale prototype

As a way of exploring the findings of the tactile investigations in an architectural context, 1:1 scale prototype of a part of a room was created (see Chapter 5, *The Prototype*). The aim was to test how the knitted textures performed on a larger scale, as well as to test spacial qualities of this knitted textile.

Design proposal

Based on the findings from making the prototype, a design proposal for a waiting room has been developed (see Chapter 6, *Design Proposal*). This room-scale project allows for in-depth application and investigation of both texture and space.

Tools

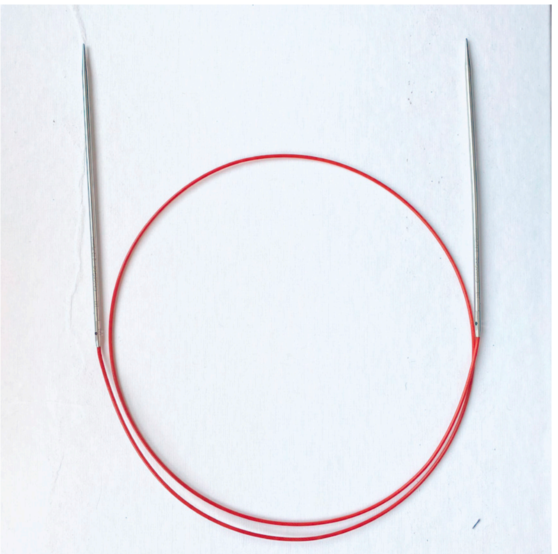
Hand knitting

Hand knitting is carried out on circular needles (fig 3.2: 2.75 mm, length 80 cm), knitting both in straight rows and in the round. Given my previous experience with hand knitting, this method lends higher precision for each individual stitch. It is also possible to freely alter knit and purl stitches when hand knitting. This freedom comes at the cost of time, with even a small sample taking long to complete, even for an experienced knitter like myself.

Knitting machine

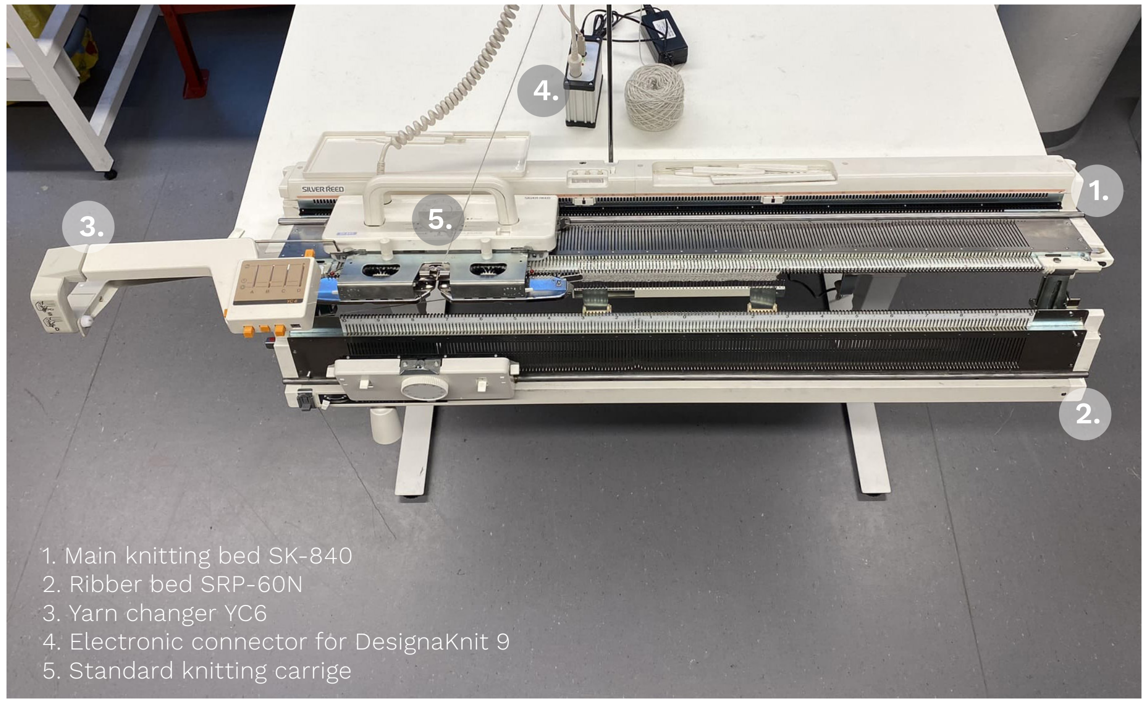
Two different knitting machines have been used for this thesis, Brother KH-930 as well as Silver Reed SK-840 (fig 3.4). Both of these machines are electronic standard gauge machines, and can be seen as equivalent to each other. These machines have been developed for domestic use, rather than large-scale production, and thus comes with limitations regarding possible sizes for knitted samples. They are maneuvered manually by dragging the knitting carriage back and forth across the knitting bed, knitting stitches on individual needles (fig 3.3). It is also possible to use digital punch cards (see header *Digital pattern making*). In addition, both machines are equipped with color changers, and the Silver Reed is equipped with the ribber bed SRP-60N attachment (which enables knitting in the round as well as knitting alternating knit and purl stitches).

The knitting machine lends itself to faster, more efficient work than hand knitting, but at the cost of freedom in altering stitches in the way I as a knitter deem most fitting for the wanted result. By using the ribber bed and DesignaKnit 9, some of this can be overcome. The time won by using the machine also means the possibility to carry through more experiments, and at a larger scale, than would have been possible using only hand knitting. Because of this, the majority of the work has been done using the knitting machines.



3.2 Circular needles for hand knitting

3.3 Close up of active fair isle knit on the machine

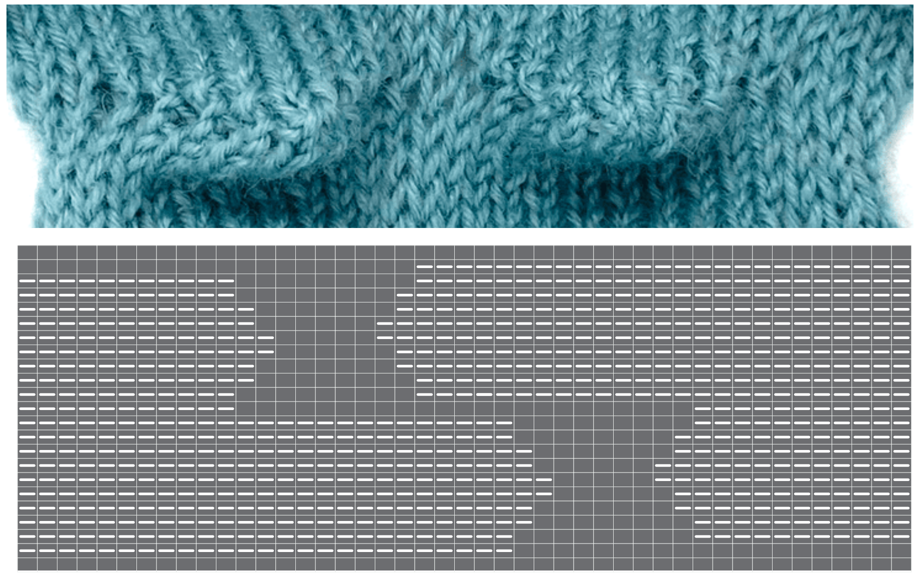


3.4 Complete knitting machine set-up

Digital pattern making

The digital software DesignaKnit 9 can be connected to the knitting machine to utilize digital punch cards, feeding the knitting machine with information of stitch type as a binary system (0 = normal knit, 1 = knit with chosen stitch type). Below the punch cards for two different samples are illustrated, partial knit using slip stitches (fig 3.5) and a tuck pattern using tuck stitches (fig 3.6)

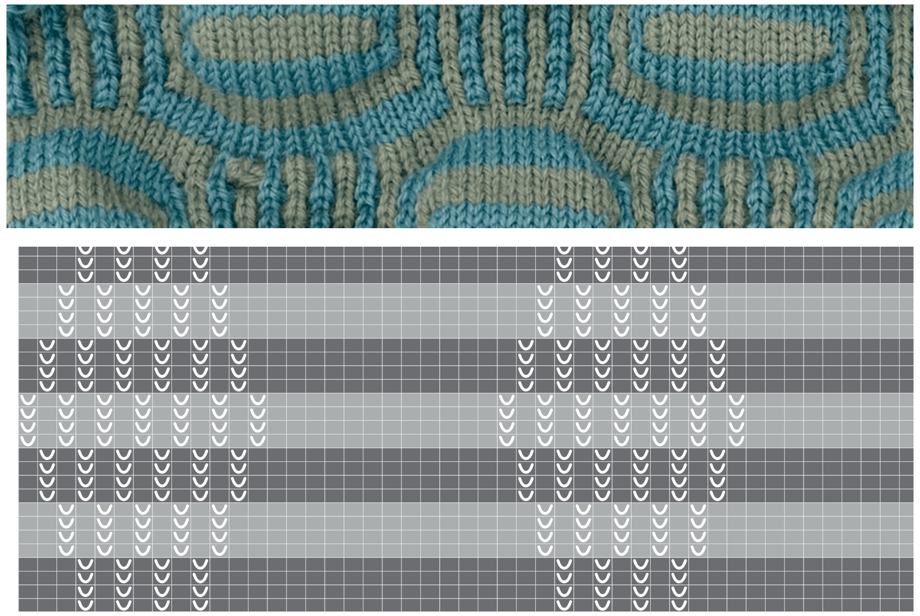
Partial knit in 1 color



0 = Knit stitch   1 = Slip stitch

3.5 DesignaKnit 9 knit chart example for partial knit sample

Tuck stitch in 2 colors



0 = Knit stitch   1 = Tuck stitch

3.6 DesignaKnit 9 knit chart example for tuck stitch sample

Materials

Within the scope of this thesis, material is defined as the type (i.e. cotton or wool) and size (i.e. weight of yarn) of fiber used to create knitted textile. This means for example differentiating between a lace weight and a fine weight cotton. Weights of yarn are defined according to the Craft Yarn Council (n.d.).

Through evaluation of the initial swatches, the following materials were found most useful for further texture explorations. For further exploration of materials and their critical evaluation, see Appendix A.

Cotton

Cotton is a natural fiber derived from plant material. It gives a hard fiber which lacks elasticity. Cotton can be mercerized to change the appearance of the fiber, adding luster and making colors appear brighter (The Fabric of Our Lives, 2022). Cotton cannot be felted. Fig. 3.7 shows fine weight, mercerized cotton and fig. 3.8 shows lace weight, untreated cotton.

Wool

Wool is a natural fiber derived from various animal furs. The specific fiber used have different tactile properties.

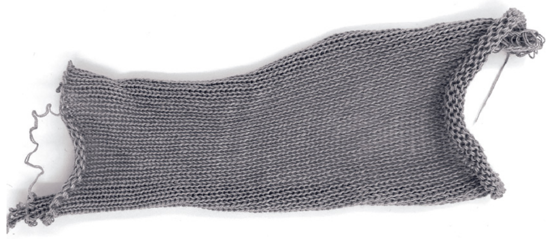
Sheep's wool

Virgin wool has a coarse, airy structure with some flexibility to it (see fig. 3.9). As it has not been treated in any way other that dyeing and it can be felted. Felting occurs when the fibers of the wool hook together when subjected to heat and wetness, creating a dense, non-flexible material. Felting also causes shrinkage. Fig 3.10 shows sheep's wool felted together with cotton thread. As the wool has shrunk, but the cotton remains unaffected, the cotton threads droop across the surface of the sample.

Sheep/alpaca wool blend

Alpaca fibers add more smoothness than pure sheep's wool but with a similar degree of flexibility (fig 3.12). This yarn is also untreated and can be felted, as can be seen in fig. 3.12, where it has been combined with a fine weight cotton thread.

3.7



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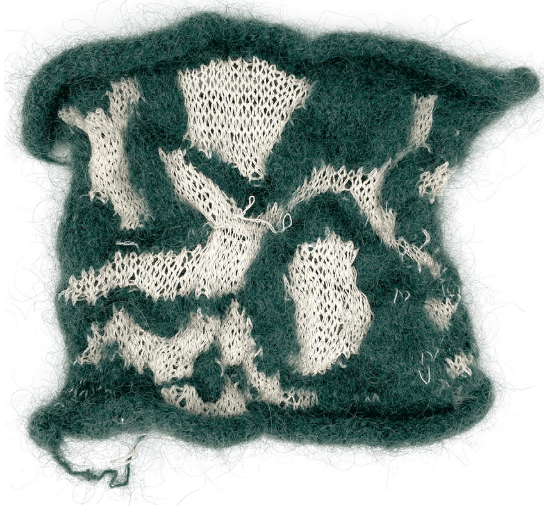

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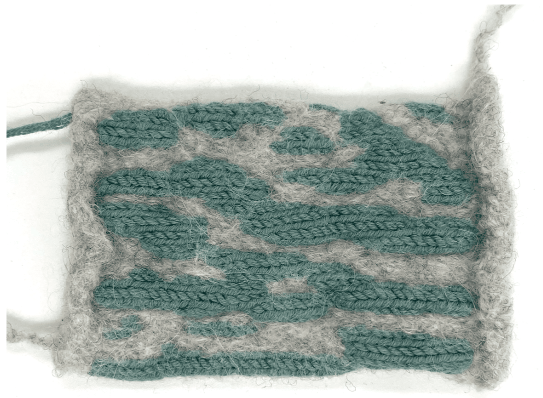
3.11



3.12

3.7 Mercerized cotton, fine weight, machine knit, 2 strand
3.8 Untreated cotton, lace weight, machine knit, 2 strands

3.9 Sheep's wool, fine weight, hand knit, 1 strand
3.10 Sheep's wool, fine weight (green) and cotton, lace weight (white), felted

3.11 Wool/alpaca blend, super fine weight, machine knit, 1 strand
3.12 Wool/alpaca blend, super fine weight, (grey) and cotton, fine weight (blue), machine knit, 1 strand each, felted

Chapter 4.

Knit explorations

4.1 Selection of samples from material and technique explorations

Knitting techniques

As part of the initial investigation of knitted textiles, a variety of techniques have been explored for their tactile qualities (some of these are presented in fig 4.1). Shown here are the techniques that were deemed most relevant for the continuation of the design process. For more examples and their critical evaluation, see Appendix B.

Stockinette knit

Stockinette knit, shown in principle in fig. 4.2, is created by knitting all knit stitches on one side (fig 4.3) and all purl stitches on the other side (fig 4.4). It results in a smooth surface that does not offer tactility through irregularities in the structure, but rather through the properties of the yarn/thread used to create it.

Fair isle

Stockinette knitting with alternate colors while letting the resting color yarn follow along at the back of the knit is known as fair isle (fig. 4.5 and 4.6). The yarn which is not knit and follows along creates what is known asd a float (fig. 4.7). It allows for visual patterns as well as texture contrast within the knit. The floats also offer interesting interaction with the textile.

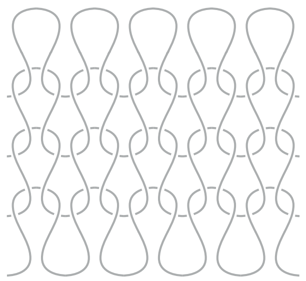
Alternating knit and purl stitches

The most common variation of alternating knit and purl stitches is rib knitting, where knit and purl stitches are alternated course-wise but maintained the same wale-wise, in for example a 1x1 as shown in fig. 4.8 and 4.9. This also adds additional stretch to the fabric. Alternating knit and purl stitches can also be used to add volume to the fabric as a whole, as can be seen in fig. 4.10.

4.2 Illustration of stockinette principle, knit side
4.3 Stockinette, cotton, knit side
4.4 Stockinette, cotton, purl side

4.5 Illustration of fair isle, knit side
4.6 Fair isle, cotton and polyamid/cotton, knit side
4.7 Fair isle, cotton and polyamid/cotton, purl side with floats

4.8 Illustration of rib knit, 1x1
4.9 Rib knit, wool/alpaca blend, 1x1
4.10 Alternating rib pattern, wool, 5x5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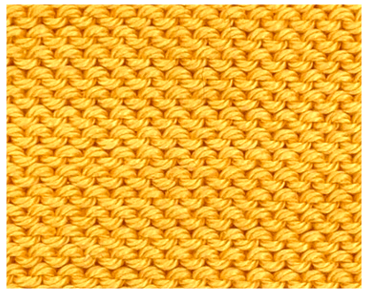
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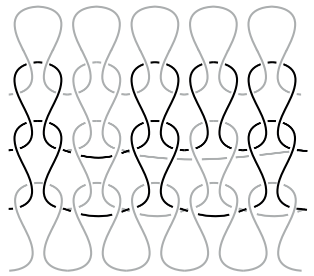
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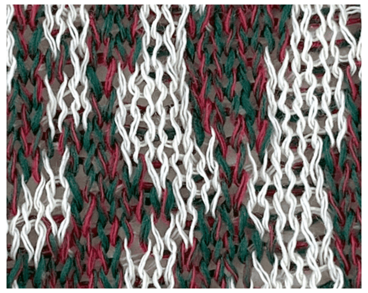
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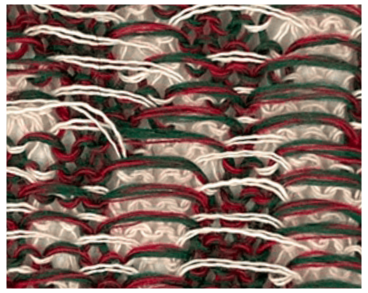
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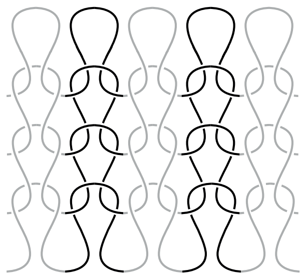
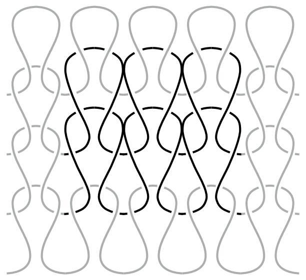
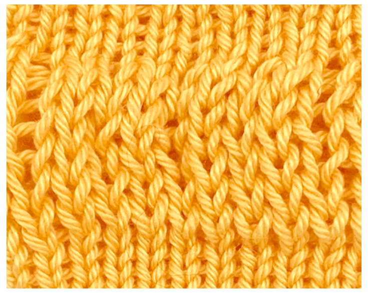

4.8


4.9

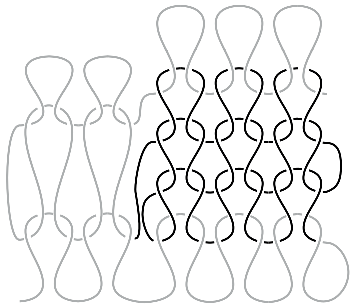

4.10

Technique-specific elements highlighted in black


4.11

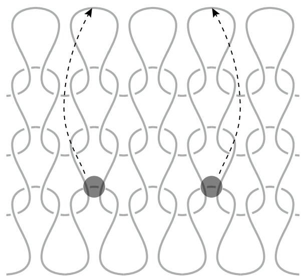

4.12


4.13


4.14


4.15


4.16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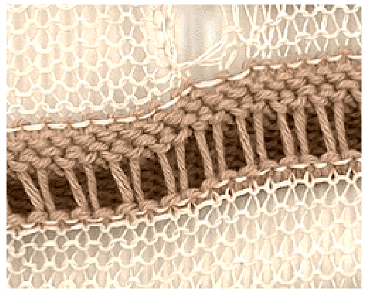
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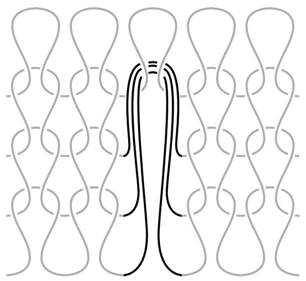
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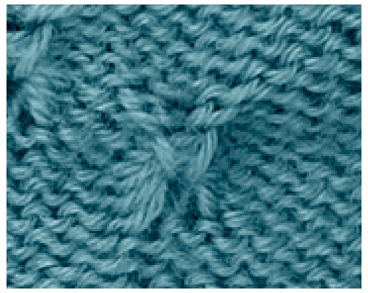
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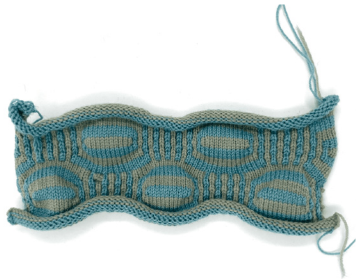

4.22

Technique-specific elements highlighted in black

Drop stitches

By casting on a new stitch between two stitches, knitting this stitch for a number of rows, and then releasing said stitch, extra space is given to those stitches surrounding the dropped stitch (fig. 4.11 and 4.12). This generates larger, looser stitches and thus a looser patch of knit, as demonstrated in fig. 4.13.

Partial knit

Partial knit, or short rows, are created by knitting some but not all stitches in a course. As demonstrated in fig. 4.14 and 4.15, the wales of knit for these stitches will consist of more stitches than the rest of the knitting, making them longer. This creates parts of the knit that are longer, or that sticks our from the surface of the knit like in fig. 4.16.

Picked stitches

By picking up the loop of a stitch further down a wale, and knitting it together with the active stitch, a pulling effect is achieved (fig 4.17 and 4.18). This can be done systematically across an entire course, resulting in folds on the knit side of the fabric (fig. 4.19) or more randomly with single stitches.

Tuck stitch

To generate a tuck stitch, a stitch is left not knitted for one or several rounds, creating a float at the back of the knit where the yarn is simply carried through. The tuck consists of finally knitting all these floats together once the stitch is put back into knitting again (fig. 4.20). This creates a puckering effect on the purl side as seen in fig. 4.21. By also alternating the color of the yarn, graphic patterns can be created using this technique (fig. 4.22).

4.11 Illustration of drop stitch, knit side
4.12 Drop stitch, cotton, knit side
4.13 Drop stitch, merino wool, knit side

4.14 Illustration of partial knit, knit side
4.15 Partial knit, cotton, knit side
4.16 Partial knit, wool, side view

4.17 Illustration of picked stitches, knit side
4.18 Picked stitches, cotton, purl side
4.19 Picked stitches, cotton, knit side

4.20 Illustration of tuck stitch, knit side
4.21 Tuck stiches, wool, purl side
4.22 Tuck stitches, wool and merino wool, knit side

Discussion on knitting techniques

The techniques investigated all work towards creating interesting tactile stimulation. In terms of engagement, the techniques that were deemed the most interesting were high on levels of volume, softness and responsiveness. When tactile qualities are also communicated through the visual expression, it engages its users to a higher degree.

Volume can be created through several methods. One is to create bumps and waves in the fabric by gathering techniques such as partial knitting, tuck stitches (both seen in fig 4.23) or picked stitches (fig 4.24). This causes the fabric to fold onto itself, generating larger volume effects that can be picked at and traced with the hand. Secondly, volume can also be achieved by using alternating knit and purls stitches, with effects varying from small scale effects more easily felt with the fingertips rather than the whole hand, to the folding of the entire fabric when alternating the order of rib knitting (fig 4.10). Thirdly, felting wool yarn, especially in combination with cotton in a fair isle pattern will pull the textile together, creating volume (fig 4.25).

Looking at the evaluation criteria, softness and volume seem to coincide, especially for wool yarns. This is reasonable as a springy material like wool will generally allow for a lot of compression, a quality which becomes more apparent when the volume is also larger. This also suggests that the technique needs to be considered in combination with the chosen material to understand its full haptic effect; it is not enough to only consider one or the other.

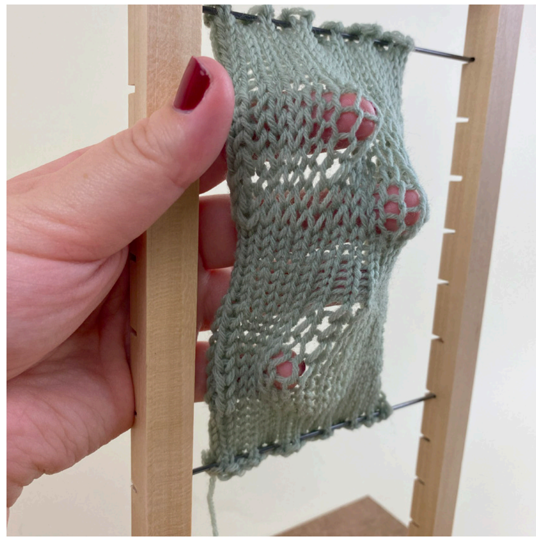
For many of the samples, it is the responsiveness of the knit that creates the excitement. The bumps generated when knitting partial knit on smaller parts of the fabric are great examples of this, generating both a "hole" to push into, as well as the possibility of pushing the bump back and forth between sides. A similar "pushing around" sensation can be generated by patches of dropped stitches which create looseness in the fabric (fig 4.26). The loops of picked stitches also create penetrability by creating strands that can be looped under, into the valley created by the fold (fig 4.27). Floats created when knitting fair isle are also great for looping under.

Contrast seems to enhance the tactile experience and the level of engagement. This could be as the haptic input varies, causing more time to pass before the sensory system has adjusted and dismisses the input. The contrast between different textures creates interesting borders that initiates lingering touch. The contrast can be between soft and rough, thick and thin, or dense and loose. This can be achieved by alternating which fiber is being used, the thickness of the fiber, the tension with which it is being knit, or with some parts being knit and others left loose in for example floats or dropped stitches. Secondly, contrast is also highlighted through color and opacity. Contrasting colors can help textures stand out more visually, encouraging interaction. The difference in opacity between parts of a swatch makes it more interesting to examine both sides of the fabric (fig 4.28).

4.23 Partial knit and tuck stitches

4.24 Picked stitches

4.25 Felted wool and cotton



4.26 Dropped stitches

4.27 Picked stitches, loops

4.28 Transparency between different materials

Mounting techniques

The way knit textile is mounted has great effect on its expression and tactile stimulation. As part of the material investigation, different mounting techniques have been explored and evaluated for its effect on texture and over all tactile experience. To create a fair comparison, the same material (wool/alpaca blend) and stitch pattern (a combination of tuck stitches and partial knit) was used for all samples. The non-mounted sample A can be seen in fig. 4.29-30.

Hanging

Hanging was tested in several ways, but adhering to the idea that all vertical sides of the knit sample were left as-is.

Fig. 4.31-32 demonstrates sample B hung through attachment between two wooden bars only at the top edge. This resulted in the sample bending up onto itself, as the internal tension was higher than the gravitational pull. This also meant that the texture of the sample remain largely unaffected as compared to the non-mounted sample as it was not distorted.

By adding a second set of bars at the bottom edge, as can be seen on sample C in fig. 4.33-34, the pulling effect was reduced, resulting in a vertical presentation. However, the weight of the bars did not seem great enough to affect the texture to any significant degree.

Lastly, sample D (fig. 4.35-36) demonstrates the same principle of attaching the sample both at the top and bottom, but this time not by pinching it between the bars, but rather by hanging it from hooks on either side. The weight of the bottom bar was half that of sample C, but neither that, nor the hooks caused any significant distortion of the texture.

Inside frame

As an extension of hanging, mounting inside a frame was tested. This meant fixing all sides of the sample, but leaving both knit and purl sides free for interaction.

Sample E (fig. 4.37-38) was mounted by the sample principle as samples B and C, by pinching the fabric between a set of two frames. The knit was made slightly smaller than the frames to allow it to be mounted with some tension. This resulted in distortion of the textures,

4.29-30 Sample A: not mounted, knit and purl side

4.31-32 Sample B: hung between wooden bars at top, knit side and side view

4.33-34 Sample C: hung between wooden bars at top and bottom, knit and purl side

4.35-36 Sample D: hung from hooks on wooden bars at top and bottom, knit and purl side

4.29

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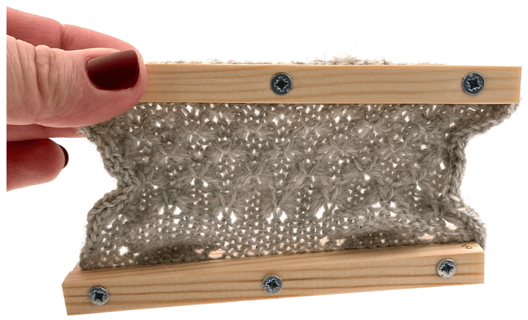
4.32



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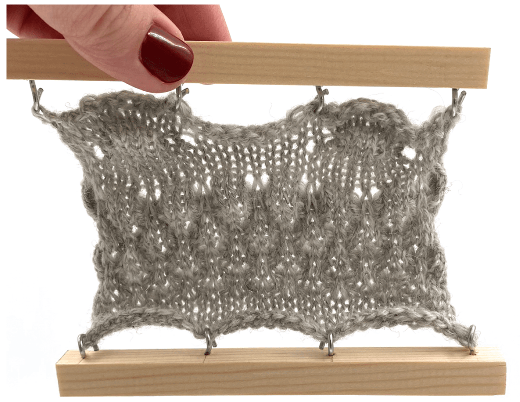

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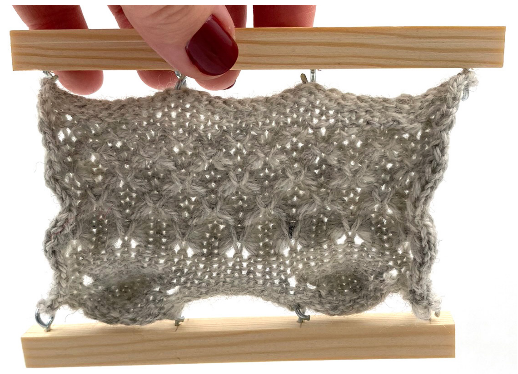


4.36

with the partial knit bumps being the most affected, losing most of their protrusion.

For sample F (fig. 4.39-40) the sample principle as for sample D was used, mounting by hooks. As with sample E, sample F was slightly smaller than the frame. In contrast, the usage of the hooks allowed for local distortion around mounting points, rather than distortion of the entire piece as was the case when pinching the entire edge. This resulted in slightly less distortion in sample F than sample E, but still enough to affect the texture. Similarly to sample E, the partial knit bumps were the most affected.

With backing

Finally, mounting against a firm background was tested, as all previous explorations had been done with the samples hanging freely in the air without any backing.

Sample G (fig. 4.41-42) was mounted by knitting the sample larger than the backing, and drawing the knit closed at the back (like a draw-string bag). Compared to the other samples, sample F was the one where the partial knit bumps stood out the most, pulling together to form small triangular protrusions on the surface.

Discussion on mounting techniques

The way through which the samples are mounted affects the texture presentation. Hanging generally creates less distortion of the texture as compared to the non-mounted sample, making the tactile experience of these samples very similar. Frame mounting seems to distort the texture, making it flatter. However, what actually had the greater effect on the texture was not the mounting in and of itself, but rather the degree to which the sample was tensioned. Higher tension led to higher distortion and flatness, going against the desired result of volume and responsiveness within the textures. With increased size of sample, the overall effect of the mounting technique also seemed to decrease, likely due to the increased weight of the textile.

The introduction of a backing material also greatly affects the tactile experience, as much of the responsiveness of the knitted textile (the stretchiness and springiness) is removed when doing so. Interestingly, volume was not decreased by mounting against a hard backing, but pieces sticking up were rather emphasized by doing so. They became a contrasting, soft focal point as compared to the smooth surface of the rest of the sample.


4.37


4.38


4.39


4.40


4.41


4.42

4.37-38 Sample E: mounted inside frame by pinching, knit and purl side

4.39-40 Sample F: mounted inside frame by hooks, knit and purl side

4.41-42 Sample G: mounted onto sheet of plywood, knit side and side view

Chapter 5.

The prototype

5.1 Completed design prototype

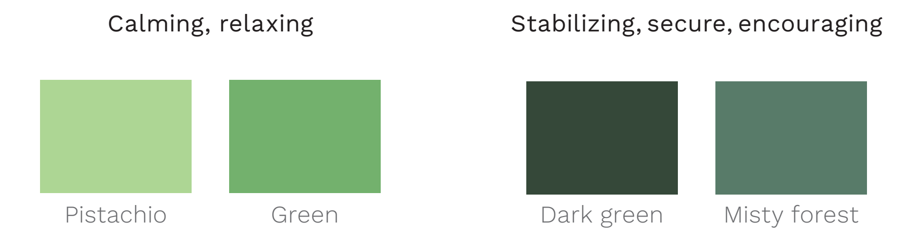
Building a full-scale protoype

To be able to apply the findings from the material investigations on a larger scale, a full-scale prototype, seen in fig. 5.1 was built. This allowed for experiencing the knit textile against the whole body, not just the hands, as well as investigating the spacial qualities that could be generated.

Design concept

Color palette

As a starting point for the design concept of the prototype, the effect of color was investigated through literature studies. Using Law-Bo-Kangs work *Atlas of Color* (2023), colors palettes with the potential of creating relaxing, calming and stabilizing moods were selected, and adapted to fit with colors available in the chosen yarn (fig 5.2).

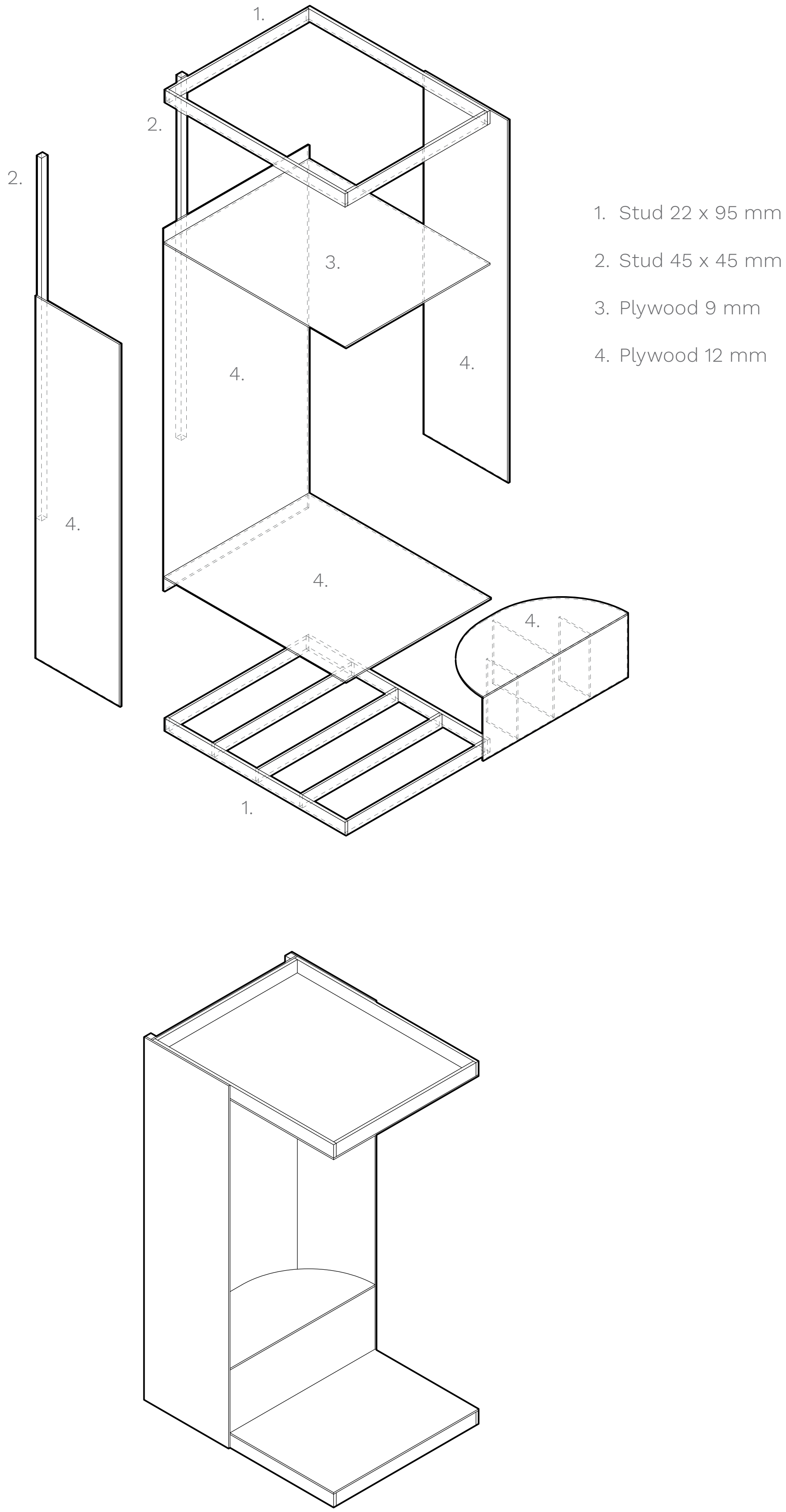


5.2 Colors available for yarn type Flora from DROPS Design A/S (n.d.) sorted according to color palette categories defined by Law-Bo-Kang (2023).

Visual inspiration

Based in the chosen color palette, the visual inspiration for the prototype is the grove and the meadow (fig 5.3), often viewed within the Nordic context as spaces for tranquility and respite. The organic expression of naturalistic elements also combine well with the expression of the knitted textiles and its textures. Tuck stitches and partial knit bumps can together form a bark-like texture, and felting wool and cotton together helps create a textured surface akin to a meadow floor.

5.3 Image inspiration for visual expression



5.4 Construction and assembly of wooden frame

Construction

Wooden frame

A wooden frame (approx. 1200 x 1500 x 2300 mm) was constructed to serve as a spacial starting point for the prototype explorations (fig 5.4). This was built from cladding boards, studs and plywood, which was attached with screws. To this, a seating area was added, also constructed from plywood and attached with screws.

Once constructed, the floor and seat were painted to create a more cohesive impression.

Knitted fabric

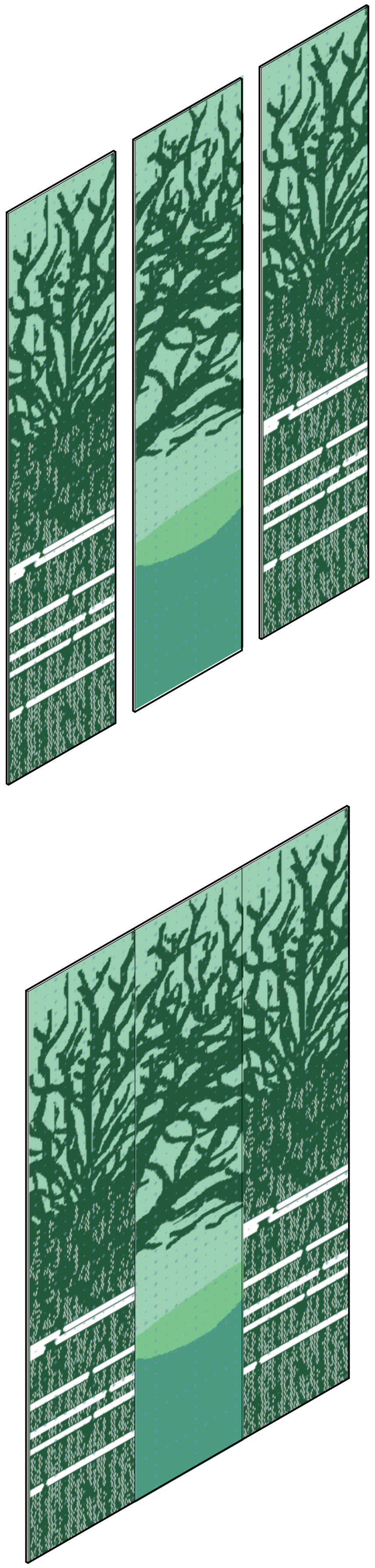
The knitted fabric consists of two main parts: a wall-ceiling piece and a seating piece. These were knitted using the Brother KH-930 machine connected to DesignaKnit 9.

The wall-ceiling piece was knitted in three parts (approx. 550 x 2550 mm each) which were then sewn together into one large piece (fig 5.5-6). This was done on a sewing machine by placing knit sides facing each other, creating a discrete seam at the front of the piece as demonstrated in fig 5.8 and 5.9. The side pieces were knitted using a combination of tuck stitch and partial knit for the tree trunks, and fair isle for the branches (fig. 5.7). The center piece was knitted using only fair isle.

The seating piece was knitted in fair isle in wool and cotton, divided over four parts (approx. 450 x 1030 mm each on average, with one curved edge and one straight edge). As seen in fig. 5.10-11, these were sewn together into one large piece (approx. 1000 x 2000 mm) by hand. This was felted using a washing machine on a 60 degree cycle at 1400 rpm, resulting in felting and shrinkage of the wool yarn (new size approx. 720 x 1150 mm) (see fig 5.12). The felting blurred much of the fair isle pattern, creating a soft gradient between light and dark areas (fig 5.13-14) and making the seams less visible (fig. 5.15-16).

Mounting of the fabric

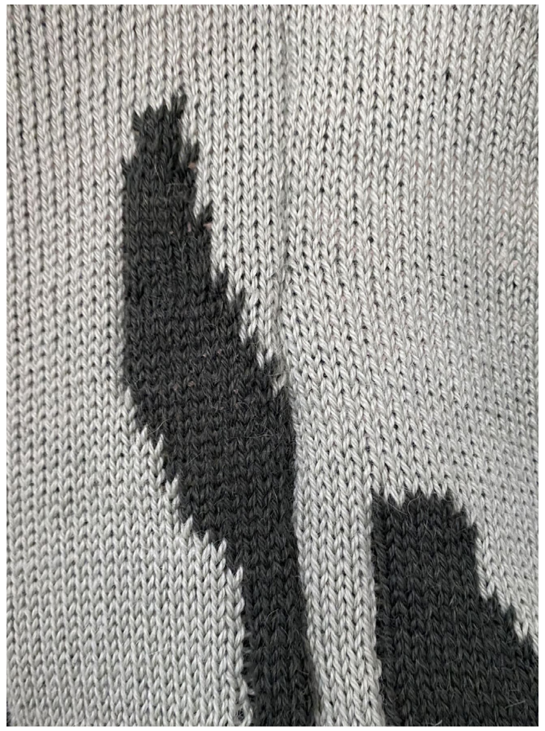
The wall fabric was mounted inside the wooden frame using two primary methods: hooks, which the fabric was attached directly onto, and eye screws, which were used as anchor points for string attached to the fabric (full assembly in fig 5.17). The hooks (fig 5.18-19) were used to create initial tension in the fabric between floor and ceiling, and the eye screw attachments (fig 5.20-21) were used to bring the fabric up along the ceiling. These points also help shape the trees in the design, giving them a rounded appearance.



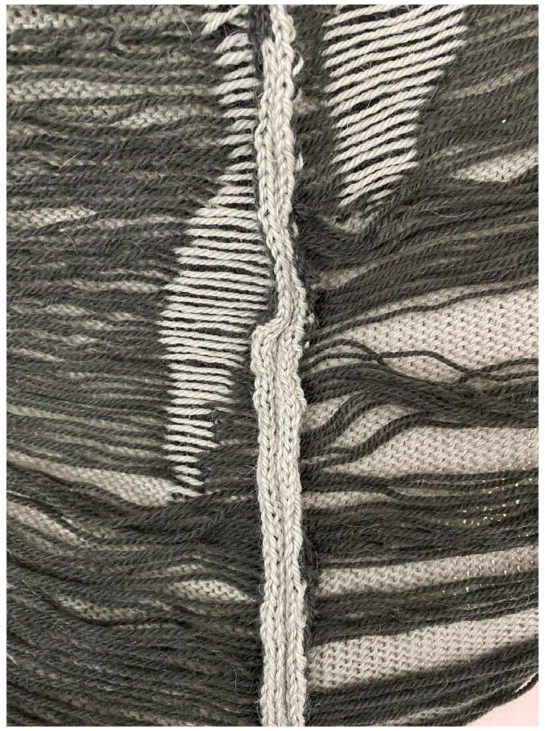
5.5 Construction and assembly of wall fabric

5.6 Finished wall fabric

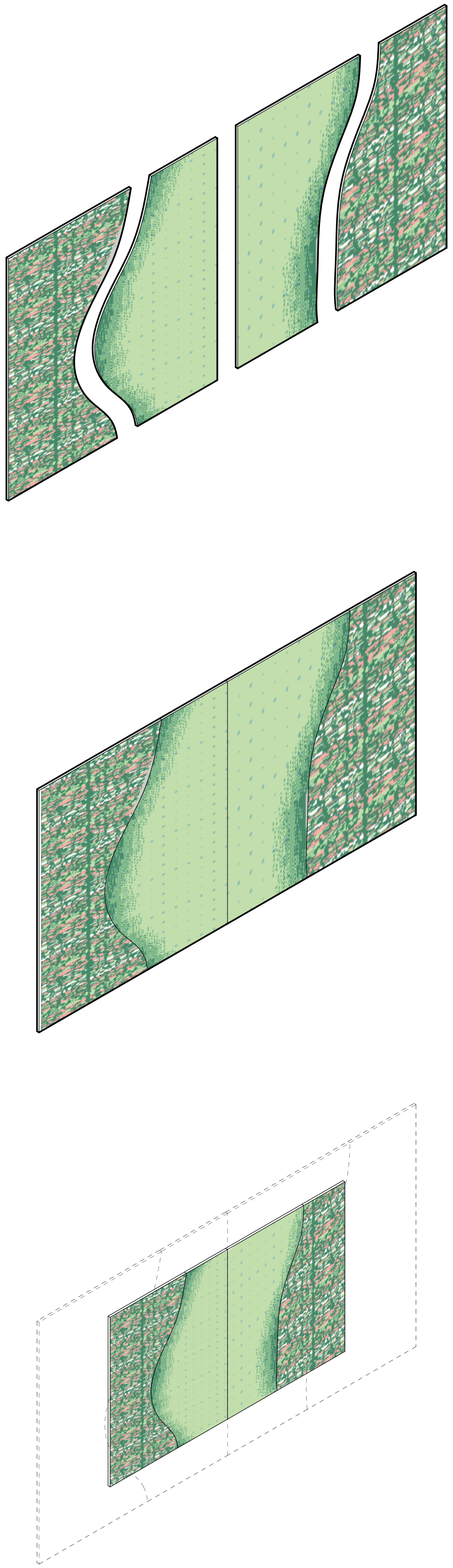
5.7 Detail of fair isle tree pattern



5.8 Seam from knit side



5.9 Seam from purl side



5.10 Construction and assembly of seat fabric

5.11 Finished seat fabric, knit side, before felting

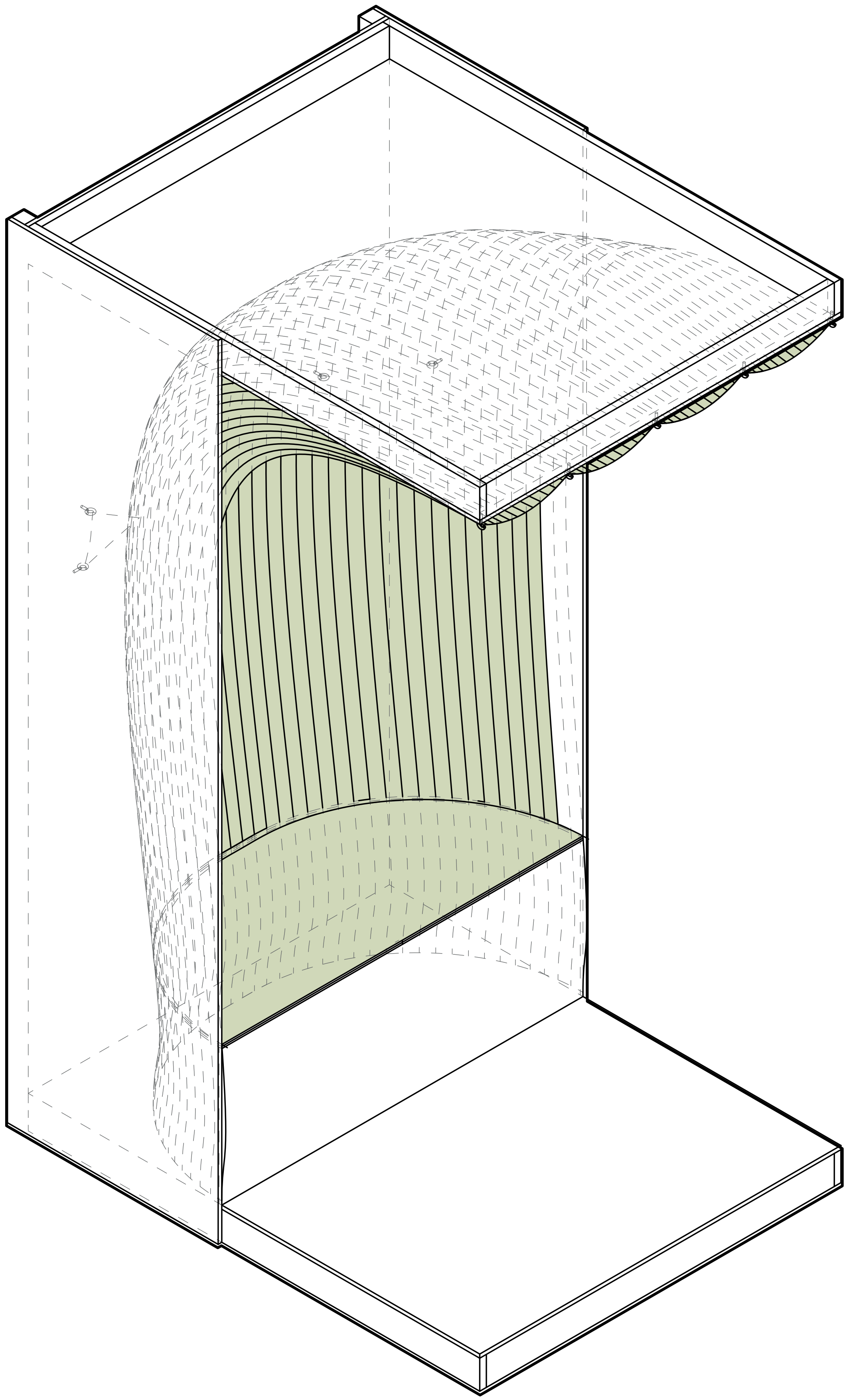
5.12 Finished seat fabric, knit side, after felting

5.13 Detail of seat fabric, knit side, before felting

5.14 Detail of seat fabric, knit side, after felting

5.15 Detail of seam, purl side, before felting

5.16 Detail of seam, purl side, after felting



5.17 Final prototype, fabric mounted

5.18 Hook attachment, ceiling

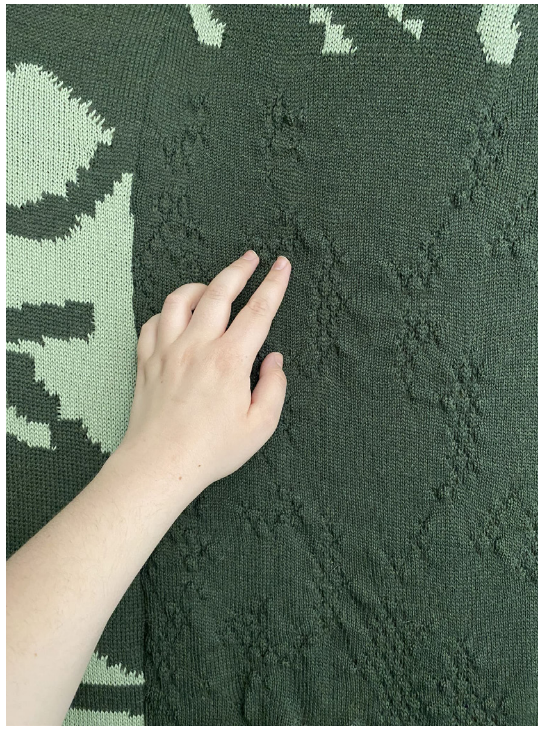
5.19 Hook attachment, side of wall

5.20 Eye screws

5.21 Eye screw, detail

5.22 Using felted sample as flooring

5.23 Seat and wall transition



5.24 Tactile surface of wall

Discussion on prototype

In the creation of the prototype, the question of feasibility in production has been central. As the knitting machine can only knit with one special stitch at a time (i.e. only fair isle, tuck stitch or slip stitch, not all combined on the same row), limitations were evident in which results would be possible to create. There were also limitations in width of the final fabric created with each knit. By knitting both the wall and seat fabrics in several sections, much of this could be overcome, although there still remained limitations in the use of color.

By placing the two trees on either side of the middle, allowing them to take up the full width of the knitted section, they could be knitted in a combination of tuck stitches and partial knit bumps, creating a tactile surface (fig 5.24). At the same time, this arrangement allowed for the seam between the piece to disappear well, only really noticeable by the branches of the canopy (fig 5.7). The darker color also helps create an intimate feeling of the space.

The felted surface of the seat is comfortable to sit on, and the concentration of texture to the sides, similarly to the wall fabric, allows for easy access. This also encourages moving ones hand from the seat up onto the wall, as there is no interruption in texture (fig 5.23). Thanks to the durability of the felted fabric, this could also function as a floor cover in a new iteration, as demonstrated in fig 5.22.

In future iterations, responsiveness should also be increased further by for example making the partial knit bumps larger and deeper. It would also be interesting to see how producing these textiles on a CNC knitting machine could affect the possibility of combining textures further.

Chapter 6.

Design proposal

6.1 Perspective of deep nook

The program of the waiting room

The effects of tactile stimulation can be related to spacial programs, as shown in chapter 2, *Background*. One such application is within low-paced environments where the need for distraction and relaxation is high, such as waiting rooms. This has been chosen as the program for the design proposal.

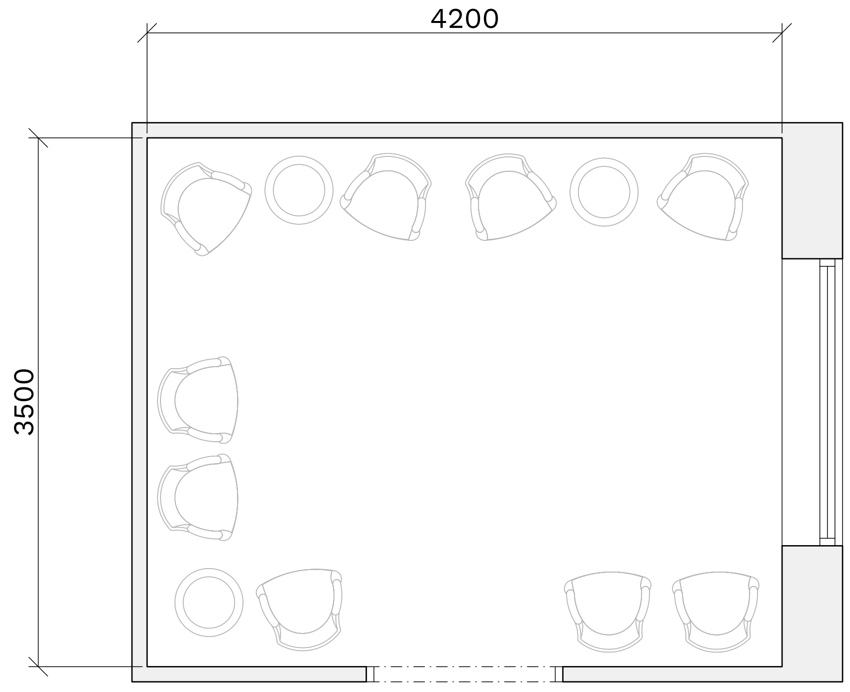
Test space

For the project, a generic waiting room is generated based on personal experience (fig 6.2). It is representative of smaller waiting room spaces within the Swedish context, with a realistic level of obstacle made up of room size and wall openings.

Analysis of needs

Based on personal observations and experiences from waiting rooms during the duration of the thesis work, needs and wants for such a space have been gathered.

The waiting room environment is required to offer a sense of comfort and safety as the visit often is connected to feelings of anxiety, discomfort, or pain. This calls for a high level of intimacy and relaxation, but also good visual overview of the room and any person that might enter it. Intimate spaces, where one can choose to what extent one wants to be exposed to the whole room, offer space for distressing and self-regulation. By simultaneously offering overview, the waiting room can help contribute to feelings of safety by preventing being caught off-guard, as well as easing the fear of missing being called on by the person you are waiting for.



6.2 Plan of test site with furnishing, scale 1:50


1. Floats from fair isle knitting


2. Partial knit bumps of varying sizes


3. Tuck stitch pattern

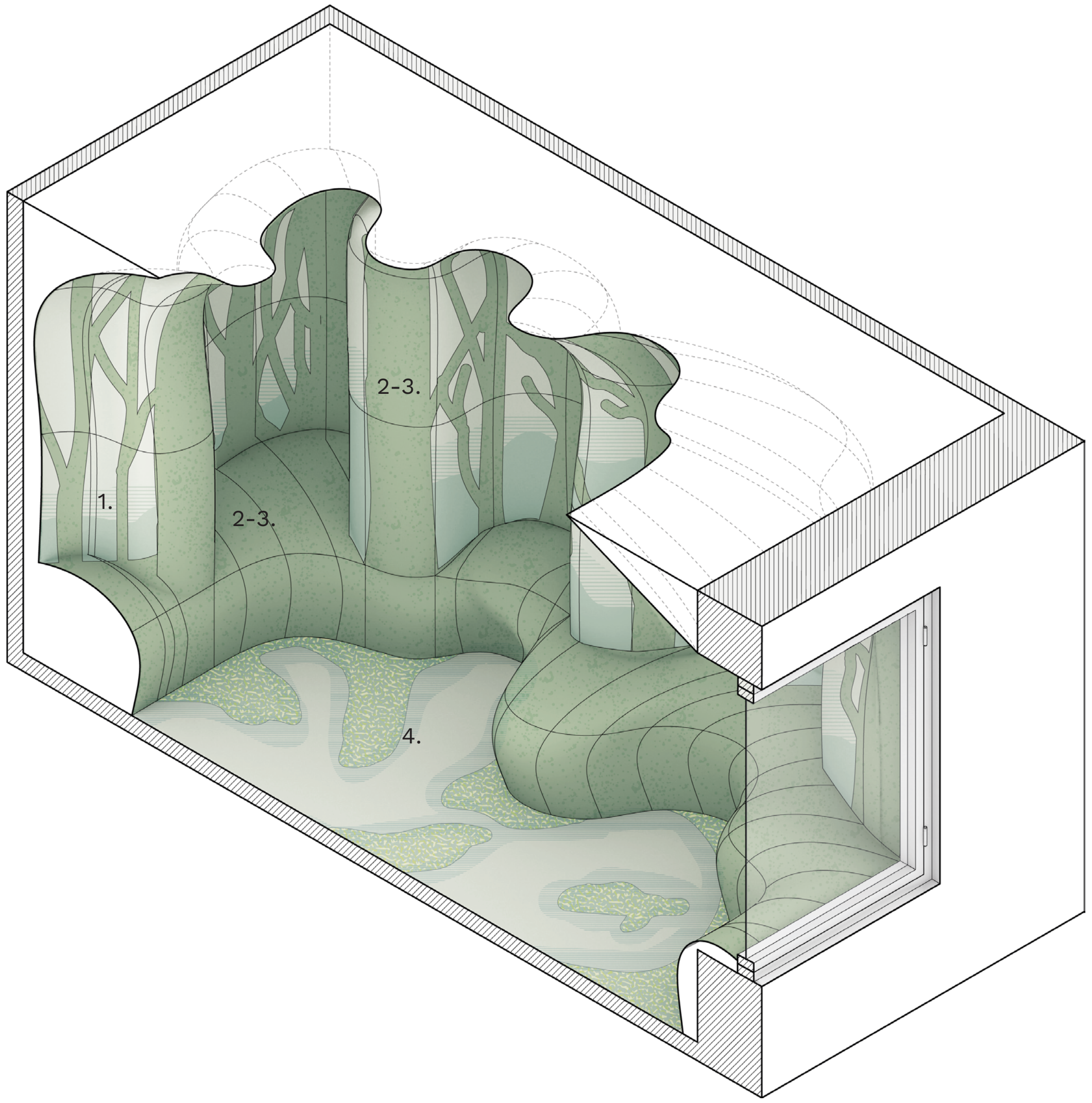

4. Felted wool and cotton

6.3 Samples for intended design

The design proposal

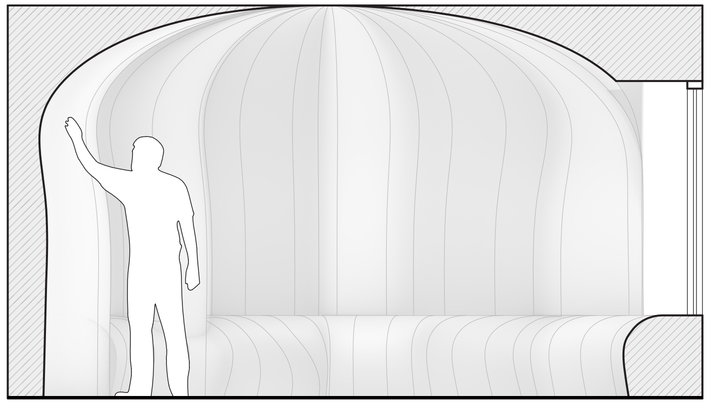
With an organically shaped interior, where the knitted walls seamlessly curve into the ceiling, this proposal offers a private and intimate setting for the waiting room. The wall folds in an out of itself (fig 6.6-8), creating smaller and larger spaces to sit or stand in, allowing the visitor to chose for themselves how exposed they want to be. The most private nooks are deep and surround the person sitting in them almost entirely (fig 6.1). In contrast, the seating by the window becomes an extension of the window sill, creating a light and open space to sit in, with the potential of enjoying the view out (fig 6.5).

Expanding the design concept of the prototype further, this space fully becomes a forest grove in varying shades of green. All surfaces are made from knitted textile, tying the room together and helping to create a comfortable acoustic atmosphere. The wall/ceiling structure is one continuously knit piece with built-in texture consisting of tuck stitches, partial knit, and fair isle (fig 6.3). The floor is a knitted and felted rug consisting of wool and cotton fair isle knitting. The felting adds durability to the floor as compared to unfelted knitting.

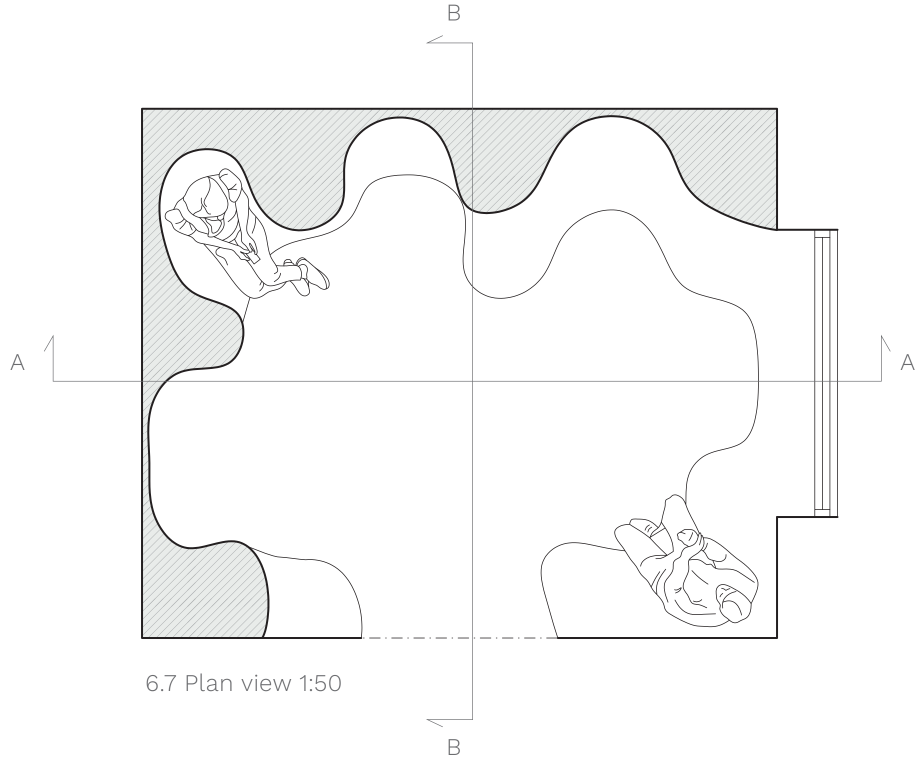


6.4 Axonometric view of design proposal

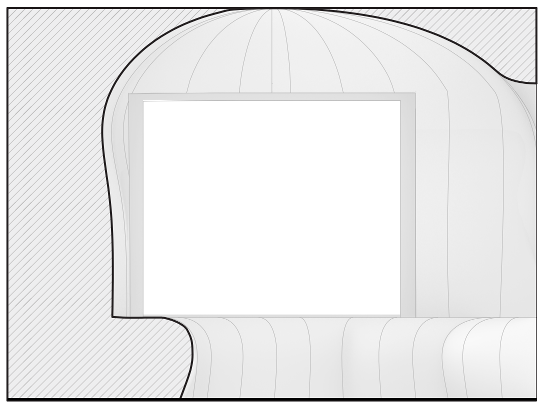
6.5 Perspective of window seat



6.6 Section view A-A 1:50



6.7 Plan view 1:50



6.8 Section view B-B 1:50

Chapter 7.

Discussion & conclusion

Discussion

Tactile and visual perception in design

Through the material explorations which investigate knitting techniques and their effect on haptic sensation (Appendix B), it can be concluded that varying such sensations can be achieved in knitted textiles. As these explorations have not focused heavily on emotional responses, but rather on haptic perception, it can not be said for certain that pleasant emotional responses will always be generated by the haptic input. However, by combining the findings of the literature studies with the results of the material explorations, it can be said that they are likely to do so.

Previous research suggests that smoother and softer textures are more pleasant that rough and hard ones (Etzi et al., 2014; Iosifyan & Korolkova, 2019). The findings from the material explorations of this work suggests that more volume and a higher degree of responsiveness of the textile is more engaging and thus distracting. As such, the combined effect of textures micro and macro scale need to be considered. It is important to note that something being pleasant does not mean it is distracting and/or intriguing. When creating spaces such as the waiting room, which ideally would provide both pleasant and distracting stimulation, it is important to note what helps make these responses possible. Is there a point where smooth also becomes boring, or where a lot of volume becomes unpleasant? What is the preferred middle way? This needs to be further investigated.

In addition, it is difficult to control individual aspects of touching within architecture as it is executed by its users. This means it is hard to control pressure and mode of touching (stroking, probing etc). As such, further research would benefit from considering several different modes of touching to help increase the understanding of the effects these aspects have on perception.

The connection between perception and cognition/emotion also needs to be considered when evaluating and developing design elements. If we connect the stimulation with previously known information that generate emotional responses, this might affect how we perceive that stimulation. For textured knitted textiles, there are several different associations. Many associate textile in general with something soft and comforting, related closely to clothing or household textiles. This is generally a positive perception. Another common association is to that of the organic shapes of the human body. This includes comforting aspects such as that of human closeness through touching or embracing. However, to some extent it also includes associations provoking disgust. such as that of skin calluses or scabs. Other aspects seem to connect more closely to the sexual nature and possible nudity of the body, such as breast-shaped volumes, creating discomfort by crossing cultural boundaries. Choosing an appropriate packaging for the design is therefore of high importance to highlight positive associations, and avoid negative cognitive ones.

What stands out most to me from doing this thesis is the joy and engagement I've been met by when allowing and encouraging touch. Passing samples around to touch seem to spread energy and engagement through the room. This has been the whole point of the thesis. To allow touch in such a touch starved community. To allow for architecture to be fun and interactable, even for grown-ups. To trigger that inherent feeling of wanting to explore with our hands, our bodies, our skin, not just our eyes. To me, it shows that we are missing something in architecture today by not fully embracing the tactile sensations that can be brought by the built environment.

Designing the waiting room

The waiting room is today often an after-thought of a space. It is a small nook in a hallway that had no better use, or a bright open space with nowhere to seek comfort. By giving these spaces a little more architectural care, the architect has a great opportunity to offer spaces that do not just put people on hold as they wait, but that rather engage and distract them for the time being. The waiting in itself can become a less obstructive part of the visit.

This thesis has not dealt with the topic of hygiene due to time constraints. However, for future research this should be central in developing these ideas further. The care facility environment is one of the spaces often brought up when discussing waiting rooms. As a result, hygiene naturally becomes part of the discussion, as a hospital waiting room which cannot be cleaned is not a very attractive one. Touching does bring with it dirt and grime which needs to be removable. As a lightweight material, textile has the potential to be constructed for easy removal, allowing it to be washed similarly to other washable textiles in care environments. For this to be feasible, the fiber used needs to be considered, ensuring it can withstand washing and disinfecting processes at high temperature. As such, wool is a poorer choice, whereas cotton would work well. Another issue which could be addressed through the choice of fiber is the potential fire hazard textiles pose. Today, natural fiber textiles are discouraged in these environments, as they are considered too high of a safety risk.

Textile and sustainability

Sustainability within architecture today is often focused around maintaining and creating materials that last for as long as possible, with as little care as possible. We struggle with materials that do not readily want to be put into a cradle-to-cradle cycle, instead of looking at the possibilities presented in materials that naturally want to deteriorate and become one with nature again. Krüger (2009) describes the deterioration of textiles as an inevitable part of its existence. She speaks about the limits of textile, how we "can't guarantee textiles for twenty-five or fifty years [...] they decompose and that is the beauty of them." (p. 8) Faegre (1979) also argues that this quality is overlooked and underrated. "Most nomad tents last only as long as the tent family itself. [...] Contrast this with our own buildings. Traditionally designed to last for generations, they are often torn down before they are worn out or left to fall down through neglect" (p. 3) In natural fiber textile, the building industry might find a material that can be readily biodegradable, but which during its life time also offers great qualities. Textile is a resource effective, lightweight, transportable, sound absorbing material, which also works great in adjusting thermal comfort. We need to open up the discussion around how long-lived we actually want our built environment to be. Looking at the United Nations 17 Sustainable Development Goals (n.d), which suggests goals within areas of development that could help ensure a more sustainable future, new approaches are needed within both our built environment and our general resource usage. Allowing for relatively short-lasting, recyclable buildings could be a new, and opposite, take from trying to create things that last hundreds of years but rarely fulfill our needs in the long run, answering to both UN goal number 11 (Sustainable cities and communities) and goal number 12 (responsible consumption and production).

Conclusion

The aim of this thesis has been to widen our understanding of how tactile elements of design affect human experience, and how this can be implemented in architecture, using knitted textile as the main material.

As shown by the material explorations, knitted textiles can offer tactile stimulation through both micro- and macro-level textures. On a micro-level, this includes softness and smoothness, generally created by the fiber used in the textile. On a macro-level, volume and responsiveness created by the knitting technique are central to the haptic experience. A combination of these micro and macro aspects can create a texture that may induce positive emotional responses when touched. Looking at previous research within the fields of haptics and architecture, haptic stimulation can have a number of positive and negative responses. Positive responses include increased happiness, better focus, as well as both increased energy and higher degrees of calmness. These responses were seem to more often be caused by macro-level haptics, such as active interaction and compression. The degree of personal movement needed to interact with tactile elements seem to affect how high in energy the response is. More interaction generates higher energy responses. Micro-level haptics seem to be more closely connected to responses of an pleasant-unpleasant nature. Here, smoothness and softness are connected to pleasantness and hardness and roughness connected to unpleasantness.

When applying these findings to architecture, a division can be made between high energy and low energy programs. Programs with high energy, such as playground and public spaces could benefit from big movement, high interaction haptics. Low energy programs would instead benefit from small movement, high interaction haptics. In both cases, smooth and soft surfaces could be preferred over hard and rough ones to increase pleasantness and as such the want to touch. As a low energy architectural program, the waiting room might benefit from haptic stimulation which require small movements but still maintain a fairly high level of responsiveness. This is likely to help create feelings of calmness and distraction, which are important in reducing anxiety and distress.

Working with material explorations as well as a full-scale prototype, a combination of alpaca-wool yarn and cotton yarn was found to generate both soft and smooth surfaces, making them pleasant to touch. In a knitted textile, texture can be implemented while still maintaining low roughness. The addition of texture instead is springy and voluminous. For the prototype, tuck stitch, partial knit and felted fair isle was investigated, producing textures of fairly high volume and responsiveness.

The spacial configuration of the room in the design proposal has been developed to fit numerous needs and wants of the visitors. There is a possibility of choosing your own level of exposure to the room. This, in combination with the tactile elements, create a space with the potential of reducing anxiety and distress.

About the author

Hanna Lundberg

I believe good architecture matters in creating happy people.

My architectural interest lies in the human experience of our surroundings, on every scale, from the interaction of our hands with materials, to the way urban structures shape our behavior.

Textile craft has been a generational gift passed down from mother to daughter in my family. For me, knitting is something therapeutic, something practical to do with my hands that makes up for the theoretical work academia presents. Through it, I have found a higher appreciation for the tactile experience, and for the time textile art requires. I am also tired of the way our society never invites touch, always saying we should not touch, only look. Through this thesis I want to give this gift that is being allowed to touch back to others, to let them experience the joy of how knits feel in your hands.

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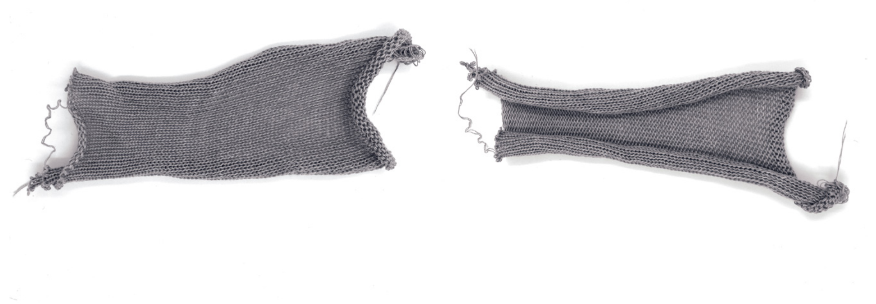
Appendix A

Critical evaluation of materials

M1 - Mercerized cotton

Fine weight, 1 strand
Machine knit, 28 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility



M2 - Untreated cotton

Lace weight, 2 strands
Machine knit, 39 sts per 10 cm

smooth	○	○	●	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	●	○	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M3 - Untreated cotton

Fine weight, 1 strand
Machine knit, 30 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M4 - Sheep's wool

Fine weight, 1 strand
Hand knit, 24 sts per 10 cm

smooth	○	○	○	○	●	rough
soft	○	●	○	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M5 - Sheep's wool and cotton, felted

Wool, fine weight, 1 strand and cotton, lace weight, 2 strands
Machine knit

smooth	○	●	○	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M6 - Wool/alpaca blend

Fine weight, 1 strand
Machine knit, 28 sts per 10 cm

smooth	●	○	○	○	○	rough
soft	○	●	○	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M7 - Merino wool, superwash

Fine weight, 1 strand
Machine knit, 32 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	●	○	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	●	○	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M8 - Viscose/polyester blend

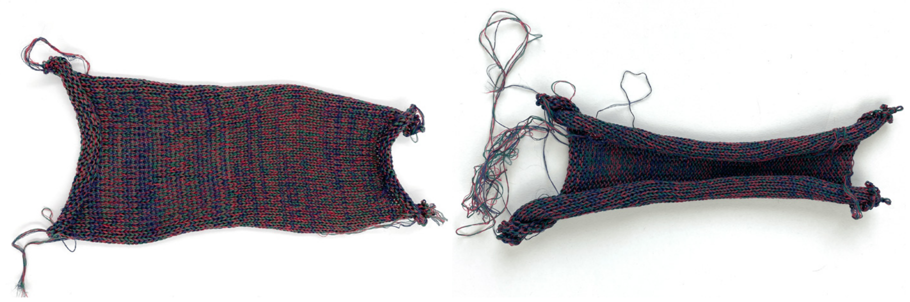
Lace weight, 2 strands
Hand knit, 30 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	○	○	●	hard
unresponsive	●	○	○	○	○	responsive
flat	●	○	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

M9 - Polyamid/cotton blend

Lace weight, 2 strands
Machine knit, 40 sts per 10 cm

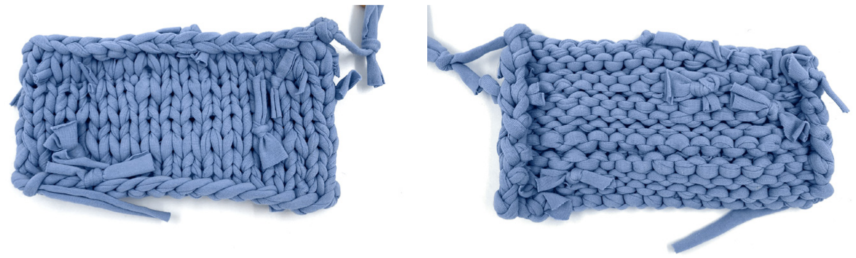
smooth	●	○	○	○	○	rough
soft	○	○	●	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	●	○	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility



M10 - Viscose/polyester blend together with polyamid/ cotton blend

Lace weight, 4 strands
Machine knit, 36 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	●	○	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility



M11 - Cotton/elastane blend

Super bulky weight, 1 strand
Machine knit, 8,5 sts per 10 cm

smooth	○	○	○	○	●	rough
soft	○	○	●	○	○	hard
unresponsive	○	●	○	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	●	○	○	○	○	high feasibility

Appendix B

Critical evaluation of knitting techniques

T1 - Stockinette stitch

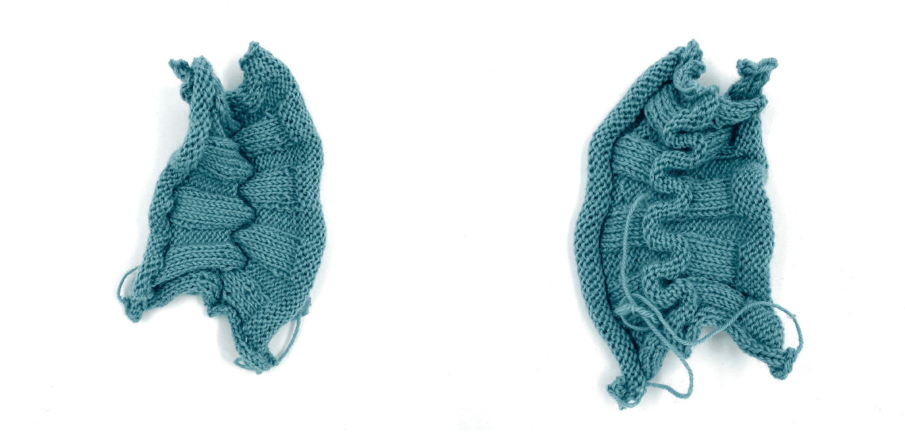
Cotton (yellow), fine weight, 1 strand and cotton (grey), lace weight, 2 strands
Machine knit, 28 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T2 - Alternating knit and purl stitches

Cotton, fine weight, 1 strand
Hand knit, 24 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	●	○	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	●	○	○	○	○	high feasibility



T3 - Alternating knit and purl stitches

Wool, superwash, super fine weight, 1 strand, 5x5 alternating rib
Machine knit, 32 sts per 10 cm

smooth	○	○	●	○	○	rough
soft	●	○	○	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	○	○	●	voluminous
low feasibility	○	○	●	○	○	high feasibility

T4 - Alternating knit and purl stitches

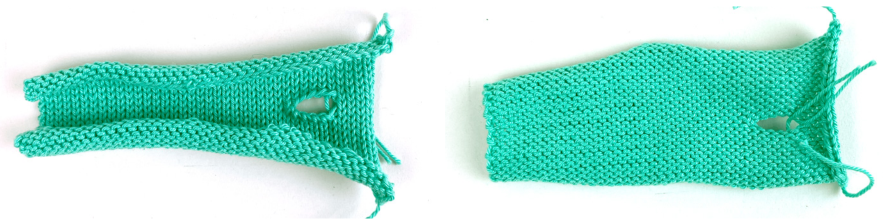
Cotton, fine weight, 1 strand, 1x1 rib
Machine knit, 44 sts per 10 cm (relaxed)

smooth	○	○	○	○	●	rough
soft	○	●	○	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T5 - Alternating knit and purl stitches

Cotton, lace weight, 2 strands, 1x1 rib
Machine knit, 40 sts per 10 cm (relaxed)

smooth	○	○	○	○	●	rough
soft	○	○	○	●	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility



T6 - Holes

Cotton, fine weight, 1 strand
Machine knit, 28 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	●	○	○	○	hard
unresponsive	○	●	○	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	●	○	○	high feasibility

T7 - Dropped stitches

Cotton, fine weight, 1 strand
Hand knit, 24 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	○	●	○	○	hard
unresponsive	○	○	●	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	●	○	high feasibility

T8 - Dropped stitches

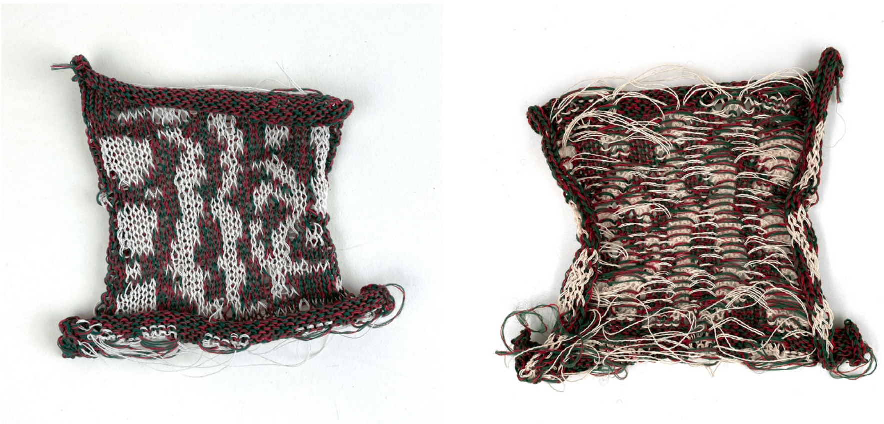
Merino wool, fine weight, 1 strand
Machine knit, 22 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	●	○	○	○	hard
unresponsive	○	○	●	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	●	○	high feasibility

T9 - Dropped stitches

Cotton, lace weight, 2 strands
Machine knit, 40 sts per 10 cm (knitted strips)

smooth	○	○	○	○	●	rough
soft	○	○	○	●	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility



T10 - Fair isle

Cotton (white), lace weight, 2 strand and polyamid/cotton blend (red/green), lace weight, 2 strands
Machine knit, 32 sts per 10 cm

smooth	●	○	○	○	○	rough
soft	○	○	●	○	○	hard
unresponsive	○	○	●	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T11.1 - Fair isle

Wool/alpaca blend (gray), super fine weight, 1 strand and cotton (blue), fine weight, 1 strand
Machine knit, 32 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	●	○	○	○	hard
unresponsive	○	●	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T11.2 - Fair isle

Wool/alpaca blend (gray), super fine weight, 1 strand and cotton (blue), fine weight, 1 strand, felted
Machine knit, 32 sts per 10 cm, shrinkage to 65% of original size

smooth	○	○	○	●	○	rough
soft	○	●	○	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	○	○	●	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T12.1 - Fair isle

Wool/alpaca blend (gray), super fine weight, 1 strand and cotton (blue), fine weight, 1 strand
Machine knit, 32 sts per 10 cm

	1	2	3	4	5	
smooth	○	●	○	○	○	rough
soft	○	●	○	○	○	hard
unresponsive	○	●	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T12.2 - Fair isle

Wool/alpaca blend (gray), super fine weight, 1 strand and cotton (blue), fine weight, 1 strand, felted
Machine knit, 32 sts per 10 cm, shrinkage to 65% of original size

	1	2	3	4	5	
smooth	○	○	●	○	○	rough
soft	○	○	○	●	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T13 - Fair isle

Merino wool, super wash (green), super fine weight, 1 strand and cotton (white), lace weight, 2 strands
Machine knit, 40 sts per 10 cm

	1	2	3	4	5	
smooth	○	●	○	○	○	rough
soft	○	●	○	○	○	hard
unresponsive	○	○	●	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T14 - Tuck stitch

Wool/alpaca blend (yellow and green), super fine weight, 1 strand
Machine knit, 32 sts per 10 cm

	1	2	3	4	5	
smooth	○	○	●	○	○	rough
soft	●	○	○	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T15 - Tuck stitch

Wool, super wash, super fine weight, 1 strand
Machine knit, 34 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	○	●	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	○	●	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T16 - Tuck stitch

Wool, super wash, super fine weight, 1 strand
Machine knit, 32 sts per 10 cm

smooth	○	○	○	○	●	rough
soft	○	●	○	○	○	hard
unresponsive	○	○	●	○	○	responsive
flat	○	○	○	●	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T17 - Tuck stitch

Wool/alpaca blend, super fine weight, 1 strand
Machine knit, 32 sts per 10 cm

smooth	○	○	○	○	●	rough
soft	●	○	○	○	○	hard
unresponsive	○	○	○	○	●	responsive
flat	○	○	○	○	●	voluminous
low feasibility	○	○	○	○	●	high feasibility

T18 - Tuck stitch

Wool, superwash (blue), super fine weight, 1 strand and merino wool, superwash (green), super fine weight, 1 strand
Machine knit, 32 sts per 10 cm

smooth	○	○	○	○	●	rough
soft	○	●	○	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	○	●	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T19 - Tuck stitch

Wool, super wash (blue), super fine weight, 1 strand and wool/alpaca blend (dark gray), super fine weight, 1 strand
Machine knit, 32 sts per 10 cm

smooth ○ ○ ○ ● ○ rough
soft ○ ● ○ ○ ○ hard
unresponsive ● ○ ○ ○ ○ responsive
flat ○ ● ○ ○ ○ voluminous
low feasibility ○ ○ ○ ○ ● high feasibility

T20 - Picked stitch

Cotton (brown), fine weight, 1 strand and cotton (white), lace weight, 2 strands
Machine knit, 32 sts per 10 cm

smooth ○ ○ ● ○ ○ rough
soft ○ ○ ● ○ ○ hard
unresponsive ○ ○ ○ ● ○ responsive
flat ○ ○ ○ ○ ● voluminous
low feasibility ○ ○ ○ ● ○ high feasibility

T21 - Picked stitch

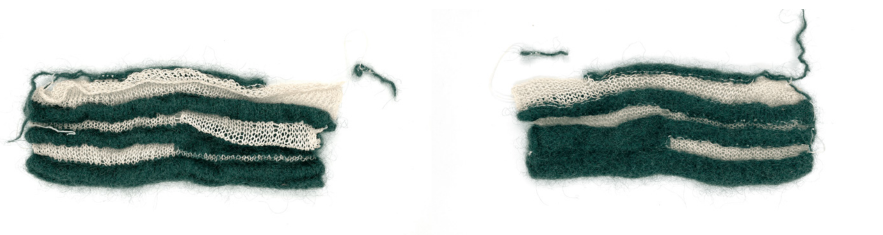
Cotton, lace weight, 2 strands
Machine knit, 34 sts per 10 cm

smooth ○ ○ ○ ○ ● rough
soft ○ ○ ○ ○ ● hard
unresponsive ○ ● ○ ○ ○ responsive
flat ○ ○ ○ ● ○ voluminous
low feasibility ○ ○ ● ○ ○ high feasibility

T22 - Picked stitch

Cotton (beige), fine weight, 1 strand and cotton (white), lace weight, 2 strands
Machine knit, 28 sts per 10 cm

smooth ○ ○ ○ ● ○ rough
soft ○ ○ ○ ● ○ hard
unresponsive ○ ○ ○ ● ○ responsive
flat ○ ○ ○ ○ ● voluminous
low feasibility ○ ○ ● ○ ○ high feasibility



T23 - Picked stitch

Wool (green), super fine weight, 1 strand and cotton, lace weight, 2 strands
Machine knit, 28 sts per 10 cm

smooth	○	○	●	○	○	rough
soft	○	○	●	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	○	○	○	●	voluminous
low feasibility	○	○	○	●	○	high feasibility

T24 - Partial knit

Cotton, lace weight, 2 strands
Machine knit, 34 sts per 10 cm

smooth	○	○	○	●	○	rough
soft	○	○	○	○	●	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	○	●	○	voluminous
low feasibility	○	○	●	○	○	high feasibility

T25 - Partial knit

Cotton (yellow), fine weight, 1 strand and cotton (gray), lace weight, 2 strands
Machine knit, 28 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	●	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	○	●	○	voluminous
low feasibility	○	○	○	●	○	high feasibility

T26 - Partial knit

Wool (green), super fine weight, 1 strand and cotton (beige), fine weight, 1 strand, felted
Machine knit, 28 sts per 10 cm

smooth	●	○	○	○	○	rough
soft	●	○	○	○	○	hard
unresponsive	●	○	○	○	○	responsive
flat	○	●	○	○	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T27 - Partial knit

Cotton, fine weight, 1 strand
Machine knit, 28 sts per 10 cm

smooth	○	○	●	○	○	rough
soft	●	○	○	○	○	hard
unresponsive	○	○	○	○	●	responsive
flat	○	○	○	○	●	voluminous
low feasibility	○	○	○	●	○	high feasibility

T28 - Partial knit

Wool, super wash, super fine weight, 1 strand
Machine knit, 30 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	●	○	○	○	○	hard
unresponsive	○	○	○	○	●	responsive
flat	○	○	○	○	●	voluminous
low feasibility	○	○	○	●	○	high feasibility

T29 - Partial knit

Cotton, fine weight, 1 strand
Machine knit, 20 sts per 10 cm (knit on every other needle)

smooth	○	○	●	○	○	rough
soft	○	○	●	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	○	●	○	voluminous
low feasibility	○	○	○	○	●	high feasibility

T30 - Partial knit

Wool/alpaca blend (dark gray), super fine weight, 1 strand and cotton (white), lace weight, 2 strands
Machine knit, 36 sts per 10 cm

smooth	○	●	○	○	○	rough
soft	○	○	●	○	○	hard
unresponsive	○	○	○	●	○	responsive
flat	○	○	○	○	●	voluminous
low feasibility	○	○	○	○	●	high feasibility

How can tactile experiences affect our mood and how can this be combined with architectural programs?

What are the specific tactile qualities of knitted textile?

How can knitted tactile elements be combined with architecture in the program of the waiting room to create spaces that might encourage feelings of comfort and positive distraction?