Virtual Fitting of Personalized Knitwear

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FIELDLAB **UPPS**

Personalized Knitwear

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And my deepest gratitude to my parents, who never stop being emotionally supportive and being proud of me.

Wenjun Zhou
July, 2019

Executive Summary

The aim of this project was to build a pleasant customer experience of personalizing, virtual fitting and ordering made-to-measure knitwear, so as to improve their satisfaction on fit as well as reduce waste in the fashion industry.

The project started with a deep dive into the design context. Relevant knowledge from academic and industry was learned, together with the technology learning on 3D virtual fitting.The research findings revealed several problems on customers' side: the lack of sensory inputs (visual and tactile) for evaluating apparel fit in online environment; the perceived complexity and uncertainty of making choices on personalized garments; the gap between one's fit requirements (depending on body sizes and personal fit preference) and actual garment sizes. The research findings also confirmed the perceived usefulness of 3D virtual fitting as a promising solution for online shopping. By using the software CLO3D, the visualization of knitwear is achievable, as well as the simulation of how the knitwear fits to different human body models.

After the analysis stage, the focus of the project was transferred to how to connect the research findings to the design. An explicit and specific design statement was established, "To design a website that enables customers to customize and order knitwear made to their measurements, in all possible looks, sizes and fits. Include the use of 3D virtual fitting in the website to boost customer confidence in evaluating clothing fit online and shopping enjoyment. In the end deliver the real garment that achieves customer satisfaction".

The design goal, along with a website framework and a list of design requirements, gave a clear guide where the design should go. During the design stage, several iteration cycles were conducted to evaluate the design effectiveness of each part of the website, so as to quickly make design decisions and refine the concept in an early design phase. The final concept was built based on both the design requirements and new inputs from design process.

In the last stage an evaluation study was carried out. A user test was done with thirteen participants using the website prototype to finish an order, and a comparison between physical try-on and virtual fitting was done with two of them. From the study results it could be evidenced that the website is able to support people to finish the online process of customizing made-to-measure knitwear, and for the majority the function of virtual fitting achieves its intended effects of enhancing customer confidence and shopping enjoyment. In the end, a review of the concept showed the validity and limitations of this project, some recommendations were discussed as well.

CONTENTS

01. INTRODUCTION

About The Project

The project is carried out in TU Delft Fieldlab Ultra Personalized Products and Services (www.upps.nl), and collaborates with the start-up company "Personalized Knitwear" (personalizedknitwear.com). The founders of this startup, an industrial designer and a fashion and textile designer, want to make an online app where customers can buy made-to-measure knitwear, so as to improve customer satisfaction on fit as well as to reduce waste. To achieve this they collaborate with Fieldlab UPPS, knitting factories and software developers. Fieldlab is working on many cases of ultra-personalized products and services, so the project has a high match with its study direction. In this project, the company shared their methods of producing knitwear and supported the concept development with relevant product information. They also supported the concept evaluation by producing real garments for participants.

The objective of the project was to develop a design with which customers can personalize, virtual fit, and order their knitwear online, enabling them to go through a set of steps towards a successful purchase(see figure 1.1). The project offers many design opportunities in identifying individual different size requirements and fit preferences and translating this information into the specifications for the garment. As customers' preference for tightness varies based on the type of garments and on which body areas considered (Shin, 2013), the project will specifically focus on knitwear fit as defined from the customer's perspective. Besides the sizes, it's also part of the customer journey to choose different looks for their personalized knitwear (i.e. fabric, style) .

figure 1.1 illustration of the process

Approach and Report Structure

The project could be divided into four stages: doing research, establishing design brief, developing the concept, and evaluating the concept. The report is not structured in a strictly chronological order, but in a similar way to how the project was carried out.

Analysis
To dive deep into the design context, an analysis was carried out with different research methods. A literature review was done to learn knowledge about apparel fit, virtual fitting technology and online customization service. Then a further investigation on the current industry was done, to see what solutions related to apparel fit have been used, and how people experience and feel about them. Different body-measuring methods were also looked at. Meanwhile, the software CLO3D for 3D garment creation and simulation was studied, in order to understand what kind of visualization can be realized and how to achieve it. The technology learning part was extended with an experiment on people's perception on virtual fabric, to better understand how well the virtual fabric could communicate its material properties.

Design Brief
During the transition stage from research to design, all the findings were incorporated and transformed into a design brief, which contains a design statement, a design framework and a list of design requirements. This directed where the future design should head to.

Concept Development
A traditional design cycle was used to enhance the design phase, which included prototype-making, rapid-evaluating and decision-making. A round of design and research activities focusing on different parts of the design were conducted. At the end of this stage, the final concept was made, based on both the new inputs from design process and the requirements proposed in the design brief.

Evaluation
In the end, a user test was performed to evaluate the final design concept. From the summarized test results, a review of the concept was stated. Then the project limitations and recommendations for improvements were discussed.

Background

The value of personalized garment
In the fashion world, many fast fashion brands produce ready-to-wear collections with mass production, low prices and large volumes of sales, allowing mainstream consumers to buy the latest clothing styles quickly and cheaply. These companies use standard patterns, production equipments, and rapid manufacturing techniques to keep costs down. For the majority of brands, clothing sizes are largely determined off of one fit model. Once a garment has been designed, all sizes are built off of its measurements via some linear grading rules (see figure 1.2).

As a consequence, clothing is designed for average demands. In the online shopping world, the market offers a variety of worldwide brands with all the sizes from XXS to XXL, hoping that each garment product will be accepted by enough customers. Due to individually-different body sizes and sizing inconsistencies across the brand, it's not easy or efficient for customers to find clothes with an exact fit for their body. In the end, many clothes are returned due to improper fit, also many end up unsold and destroyed.
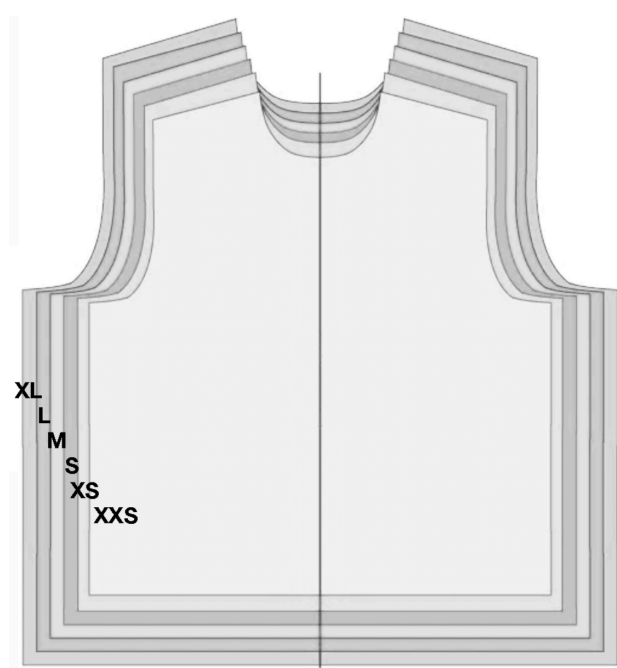

figure 1.2 pattern grading of of turning base size or sample size patterns into additional sizes

In this background, personalized garments can meet the needs of single customers or customer groups, to match size specifications of garments with customers' body measurements. Moreover, the solution also makes a sustainable contribution to the fashion industry. By producing clothes on-demand we could reduce the waste of the industry up to 30%.

The value of virtual fitting
Initially, expert tailors, designers or salespeople were the primary drivers of garment customization services and were responsible for customer consultation. These people know well about clothing design and production, so they can understand customers' needs and provide custom solutions. Since modern information technology has transformed many existing products and services in a number of ways, the internet becomes a new ideal marketplace for personalized garments sale. As more and more mainstream customers go online, online systems will take the role of skilled salespeople and enable customers to buy personalized products on their own.

When the online purchase process is placed in the hands of the non-expert customers, they will need sufficient information to evaluate garments and make decisions. Virtual fitting has been a new technology widely used in the fashion industry, which allows customers to view from the screen their look when wearing one or more pieces of clothing. The application of it enables customers to evaluate the size, fit or style of garments without physically wearing them. Virtual fitting is especially a useful technology for clothing customization companies because a custom clothing is only made after purchase, so customers cannot see the future garment in reality when making the purchase.

Company Context

Personalized Knitwear is a start-up in Delft-Rotterdam. They strive to make an on demand production line to reduce waste and make personalized garments. Personalized garments are made for every individual customer, not for the many. By doing so the company can make every piece of knitwear fit the customer best.

The company work with a collection of garments for customers to choose from. Customers can pick one model from the collection and then make a series of choices to personalize their garment, on both its look and size. After they place an order, the garment will be knitted by the company and send to them. This process will take about two to four weeks.

Currently their collection consists of only one model, this is because they want to learn everything about this model to get the sizes exactly right before the next phase of developing more models. So in this project, the design is built around their first model of Men's merino wool knitwear (see figure 1.3). The model lets customers have free choices on its neckline, color, sizes. For the neckline, the company provides three options of crew, v-neck, and cowlneck (see figure 1.4). For the color, they develop a unique color pallette. The stitch is a textural and uses two contrasting colours, which gives a deep richness to the garment (see figure 1.5). For the size, they are quite flexible about it because all the garments are made after purchase. The current method to calculate the garment sizes is to add certain extra length to body measurements. So if customers want to order custom sizes, they will need to provide their body measurements.

figure 1.3 The knitwear

figure 1.4 three options of crew, v-neck, and cowlneck

figure 1.5 Different color options

ANALYSIS

Literature research

The exploration of the design context starts from a review of relevant literature. Knowledge is studied from three aspects: apparel fit, virtual fitting technology, online customization service. In this section, what is learned is summarized into useful insights for design.

Apparel fit & fit perception

Individual preference

To increase customers' satisfaction on apparel products, it's important to identify what constitutes a good fit and how it is perceived by people. Apparel fit satisfaction evaluated by individuals tends to be subjective, which results in people's different selections of clothing (Ashdown & DeLong, 1995). Two individuals with the same body measurements could have completely different perceptions on apparel fit (Alexander et al., 2005). Fit preference varies with individuals, which depends on many factors, such as personal taste (Holman, 1981), current fashion trends, age, gender (Brown & Rice, 1992), the type of clothing, intended wearing contexts (Shin, 2013), and how satisfied a person is with his or her actual body (Coury, 2015).

What constitutes good apparel fit

Due to the various qualities of apparel, what constitutes good apparel fit can be explained in divergent ways. According to LaBat (1987), apparel fit is defined as the relationship of garments to the body, including visual analysis on fit and the physical perception on comfort. This is partly consistent with Ashdown & DeLong (1995) who noted that a wearer judges the fit of a garment based upon both visual and tactile information. Frost (1988) defined fit satisfaction as "visual as well as physical satisfaction of the garments and its function on the body". All these studies reflect that apparel fit requires sensory inputs in two dimensions: aesthetic fit and physical fit. Aesthetic fit relates to the look of the garment on the body and the overall appearance; Physical fit relates to the comfort level of wearing the garment when the body is still or moving for activities.

Aesthetic fit
the look of the garment on body and the overall appearance

Physical fit
the comfort level of wearing the garment when body is still or moving for activities.

Apparel fit ← is evaluated by ← **Sensory inputs**

Influencing factors:
- Personal taste
- Body satisfaction level
- Wearing contexts
- Type of clothing
- Fashion trends
- ...

Visual analysis
From looking in a mirror or down at themselves

Tactile feedback
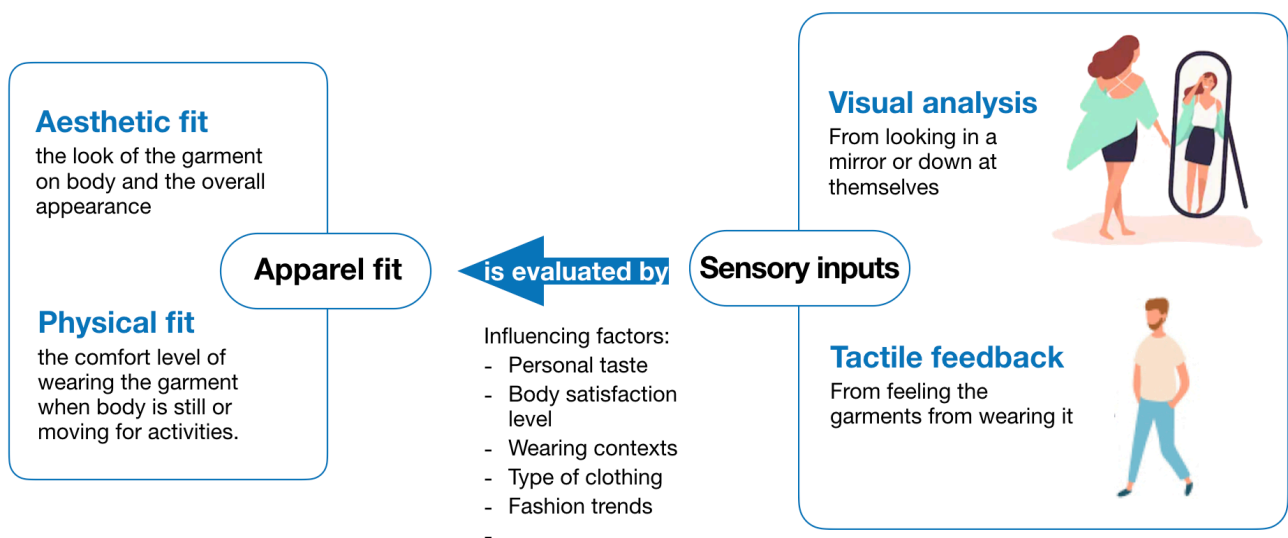From feeling the garments from wearing it

figure 2.1 illustration of what constitutes apparel fit and how it is perceived

How apparel fit is perceived by people

Since how to make garments in proper volumes and proportions to well fit the body is usually the expertise mastered by skilled fashion designers or experienced customers, ordinary people perceive apparel fit with their intuitive and subjective feelings rather than expert knowledge. When a wearer judges the fit of a piece of clothing, he learns from his sensory experience of physically trying on it. Frost (1988) mentioned customers perceive apparel clothing in two ways: (1)visual information: from looking in a mirror or down at themselves, (2)tactile information: from feeling the garments from wearing it.

E-retailing of apparel

Limited sensory experience of digital product evaluation

E-retailing has been growing over the business world, with which the marketplace lures customers with lower prices, better service and more choices (Hasan, 2016). Purchasing clothing from internet becomes widespread as it's a major online merchandise category. However, the lack of sensory inputs in online environment might cause difficulty for consumers to make an informed purchase decision (Perry, Blazquez & Padilla 2013) . The online environment can be characterized by the absence of touch experience and indirect visual experience from screen, which inevitably sets some limitations for products evaluation. It could be more of a problem for fashion industry because apparel products require higher sensory inputs for evaluation.

figure 2.2 e-retailing experience

Imagination of touch

In online environment, feedback got from sensory inputs has to be partly replaced by customers' imaginations. When touching is not feasible, imagination of touch could act as a replacement to help considering a purchase (Peck, Barger & Webb, 2013). For that most of daily-life tactile information can be interpreted through human's visual perception (Naumer & Kaiser, 2010), it's still possible for customers to overcome the lack of tactile input with other visual information on screen.

Different content of information

Compared with physical stores, the content of information online is very different in online stores. There is always extra information online such as customer reviews, fabric properties, size charts, pictures of garments worn by charming models and so on. Some studies argued that e-retailing is likely to cause confusion due to the unlimited space of provided information (Chen and Dibb, 2010; Everad & Galletta, 2006). Garaus (2018) summed up that unnecessary, inaccurate or outdated information, as well as poorly organized information tends to confuse customers during online shopping. Information overload should be carefully avoided otherwise it would make the situation too complex.

Insights for design

- People have different preferences for how they like clothing to fit their bodies.

- Apparel products require both visual and tactile inputs for evaluation, which is quite limited in online environment. To overcome this, customer might need proxy sensory experiences as a substitute for physical try-on.

- Tactile information can also be conveyed from digital screen with visual information.

- The presented information of apparel products in physical and online store are quite different. Online retailers should identify what customers really need to know about their products and organize the information in a good way.

Customer experience in 3D virtual try-on

Positive sides

Looking at the sensory enabling technology from customers' perspectives, research in online shopping shows that effective 3D virtual product presentation has a great impact improving customer attitudes towards the product and satisfaction with the website (Algharabat et al., 2017). In another study conducted by Kim and Forsythe (2009), they investigated customer experience in three sensory enablers for apparel e-retailing:"(1) 2D view (close-up view; larger view; super enlargement) and alternative views (from 2-3 angles); (2) 3D rotation views (from every angle as the consumer drags a mouse); and (3) virtual try-on (virtual model)." All of the three sensory enabling technologies were found to contribute to perceived usefulness and entertaining experience during online shopping. They facilitate customers to better evaluate the appearance and properties of the apparel, as well as providing a more engaging and pleasant e-shopping experience. For virtual try-on, what is special about this technology is that it has higher value of perceived entertainment than 2D view and 3D rotation views, whereas technology anxiety has most negative impact on its usage during apparel e-shopping. Another interesting finding in this study is that the interactive technology enhances customers' intention to reuse it and revisit the site, which means that even customers don't buy garments the first time, by letting them experience virtual try-on could increase website visits and purchase intention.

Negative sides

Despite the positive impacts of 3D virtual fitting on customer experience, some studies report the negative consequences of applying it in apparel e-retailing. One consequence could be the rouse of discomfort of viewing oneself in 3D. For that it's a rare and strange situation for people to view their body directly from behind, from all angels, so seeing a 3D avatar representing their body could give them new perspectives on their actual selves. Ridgway (2018) demonstrated that 3D views on body could frustrate people and decrease their satisfaction with their actual body, especially for women; and increase likelihood to engage in appearance management behaviors, especially for men. So people may postpone the purchase until they feel they get a better body shape. Another consequence could be the concerns emerging from using the technology, including privacy issues, availability of technology (Kim & LaBat, 2013) and technology anxiety (Kim & Forsythe, 2009).
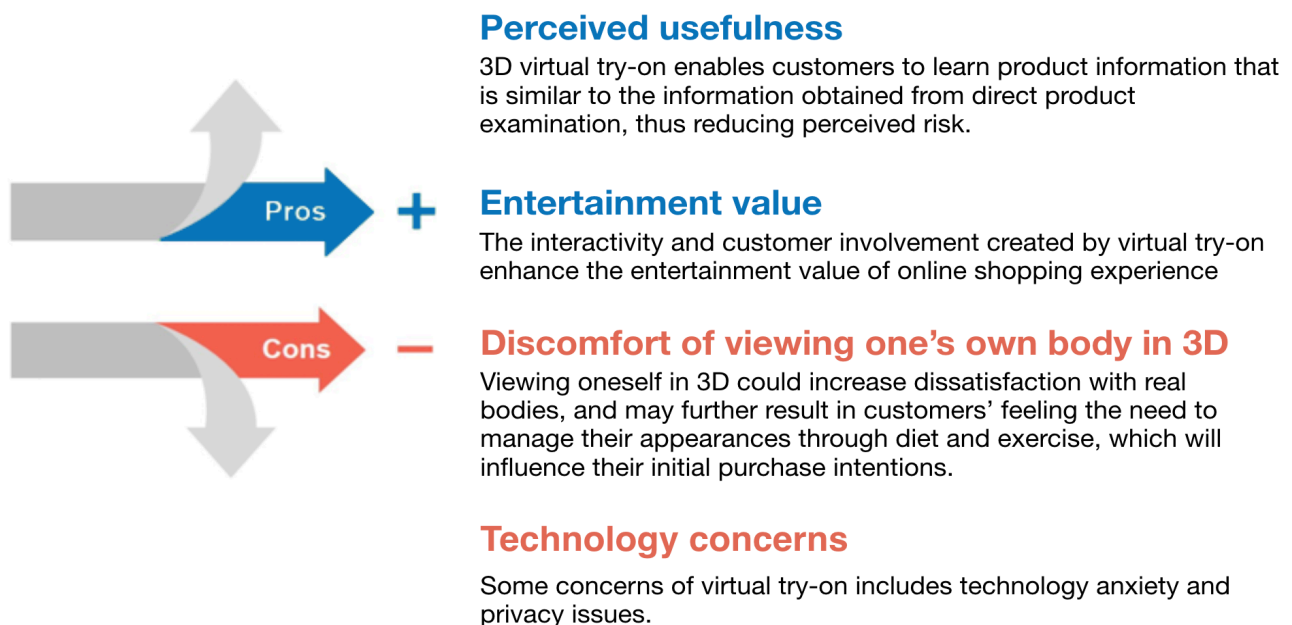

Perceived usefulness

3D virtual try-on enables customers to learn product information that is similar to the information obtained from direct product examination, thus reducing perceived risk.

Entertainment value

The interactivity and customer involvement created by virtual try-on enhance the entertainment value of online shopping experience

Discomfort of viewing one's own body in 3D

Viewing oneself in 3D could increase dissatisfaction with real bodies, and may further result in customers' feeling the need to manage their appearances through diet and exercise, which will influence their initial purchase intentions.

Technology concerns

Some concerns of virtual try-on includes technology anxiety and privacy issues.

figure 2.3 summary of impact of 3D virtual fitting on customer experience

The application of garment CAD software

Virtual garment creation

There are currently two ways of designing virtual garments: "2D to 3D" and "3D to 2D" (Sayem, Kennon, Clarke, 2010). The former refers to aligning flat digital patterns to a virtual mannequin, and the latter refers to flattening three-dimensional garment model into two-dimensional patterns. The use of CAD software permits design ideas to be implemented and validated in a very short time (Volino, Magnenat-Thalmann, 2012), which provides the possibility of presenting a visualization of personalized garments to customers.

Virtual garment simulation

The CAD software based on mechanical models of real fabric have great effectiveness in garment visualization and accurate simulation the drape of garment (Chen et al., 2015). By changing the physical parameters of fabric in the software, the visual and tactile effects of virtual garments can be easily adjusted so they can look as close as possible to real garments (see figure 2.4). In addition, some software support real-time simulation of the garment on human body models, which allows fit evaluation of a specific garment on a specific body (see figure 2.5). The virtual fitting technology can clearly show the size change, which is enough for the viewer to perceive and distinguish the size difference(Kim, 2016).

figure 2.5 Virtual garment on virtual avatars in CLO 3D

Insights for design

- 3D virtual try-on would be a good technology to use in online apparel personalization, as its functional values is acknowledged by customers. With the use of CLO3D software, a simulation of apparel fitting can be quickly realized.

- 3D virtual try-on would create higher interactivity and customer involvement, thus enhancing customers' shopping enjoyment, intention to purchase, and intention to revisit.

- Viewing a virtual body in 3D representing oneself could cause discomfort. In the design phase, how people feel about the way of presenting their virtual body needs to be looked at.

2D CAD PATTERN

CLO SAMPLE

figure 2.4 Virtual garment created by CLO

Online personalization service design

The internet brings one-to-one services directly to people, thus promoting a shift toward new business models of capturing opportunities at the customer's end of the value chain. In this background, personalized e-service could be a worthy solution as Riecken (2000) summed that "personalization is about building customer loyalty by building meaningful one-to-one relationship; by understanding the needs of each individual and helping satisfy a goal that efficiently and knowledgeably addresses each individual need in a given context".

If we look at personalization services in an evolutionary perspective, the role of end users has greatly changed. As Grenci and Wattas (2007) explained the difference between pre-internet and online customization, future customization is controlled by non-expert end users which used to be controlled by salesmen (see figure 2.6). Most non-expert customers have a very limited understanding of the product as well as their own needs. In this context, an expert system should allow for self-consultative buying and take the role of identifying needs, defining configuration options, providing expertise to customers. (Grenci & Wattas, 2007).

To enable customers to navigate all the personalization options, product configurators are the most frequently researched approach(Harzer, 2013). A product configurator, as part of the customer's learning-by-doing process, should allow for visualizing, evaluating, readjusting, and pricing different product variants, in order to remove perceived complexity and create a feeling of pleasure (Franke & Piller, 2003). Harzer (2013) further summarized the requirements on mass customization interaction systems in four aspects: reduce burden of choice, reduce preference uncertainty, reduce principal-agent problem, increase process enjoyment.

Table 1 Toward customized e-consumer services for the non-expert		
Pre-Internet customization controlled by sales person	Early/current-Internet customization controlled by expert customer	Future Internet customization controlled by non-expert customer
• Experienced with product, process	• Experienced with product only	• Inexperienced with product, process
• Consultative selling	• Revelation, Transaction buying	• Self-consultative buying
• Salesperson provides expertise	• Customer provides expertise	• System provides expertise
• Salesperson identifies needs	• Customer knows needs	• System identifies needs
• Salesperson defines configuration	• Customer defines configuration	• System defines configuration
• Product configuration systems	• User-assisted systems	• Solutions-driven systems

figure 2.6 Table of evolving customization from Grenci and Wattas (2007)

Insights for design

- End users of the design are non-expert customers who have a limited knowledge of knitwear design and production. The system should identify customers' needs for fit, translate their preference and requirements into a knitwear can be produced, rather than relying on customers to determine needed features or benefits. The system should support customers with necessary expertise to make decisions.

- It will be helpful to remove perceived complex and create pleasure by providing a co-design process for rich visualizing, readjusting and evaluating.

Industry research

To take a closer look at the current industry and market, I investigated what information is provided in popular online apparel websites and what measuring methods are currently used in made-to-measure markets. In this section more field knowledge is summarized.

Online knitwear retailing

In the previous section "E-retailing of apparel" in Chapter 2, it suggests that online retailers should identify what customers really need to know about their products and organize the information appropriately. So it's important to get a view of what specific information of knitted garments should be provided. Two research questions were asked.

Research question
1. What basic properties of knitwear need to be communicated to customers?
2. What other information could influence customers' decision?

Method
I investigated the website content of eight regular apparel brands and five apparel personalization companies, and compared their similarities and differences in online presentation of knitwear. Both visual and textual information shown on regular apparel websites are mapped out. Only textual information shown on apparel personalization companies are mapped out, because the visual presentation of knitwear are differently dependent on the co-design process (see figure 2.7).

Results analysis
1. Material and washing/care instructions are essential information.
2. "Soft" and "Ultra-fine" are two mostly mentioned characteristics in online stores to advertise a knitwear.
3. A close-up view of the knitwear is always provided to show details of the fabric texture and knit stitches.
4. All the images together should provide enough information for customers to know how the knitwear looks from different sides.
5. Regular apparel brands like presenting the knitwear on a lanky model with good-looking face. Some of them provide height and weight of the model as a size reference for customers. Fit-related information is very limited. They usually provide a general size guide for all the garments of the brand.
6. On personalization websites, the importance and the emotional effect of a model are obviously weakened. They put more emphasis on fit-related information and details about how the fabric would feel and perform. They also give fit tips on the specific garment such as "designed to lay relaxed on the body for a classic look", "sized for layering over a shirt or baselayer", which is rarely provided by regular apparel brands.

Insights for design

- For knitted garments, information essential to provide are: material, washing/care instructions, close-up view of knit stitches, the look of knitwear from different sides.

- Apparel personalization companies are usually unfamiliar to customers and have fewer product lines. To convince customers, information especially good for apparel personalization brands to convey include: fit-related information, how the fabric would feel and perform, fit tips on the specific garment.
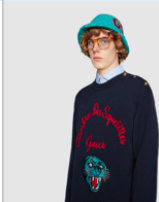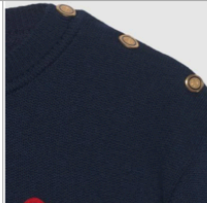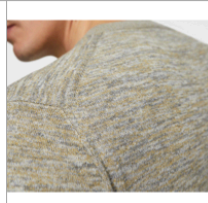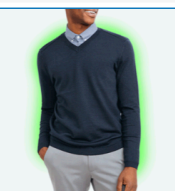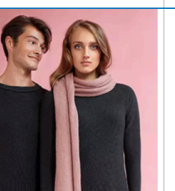
	H&M	GUCCI	HERMÈS	RALPH LAUREN	ZARA	UNIQLO	ad...
Knitwear worn by model							
overview of the flat knitwear							
overview of the knitwear in 3D							
fabric & stitches detail							
Material used	100% cashmere	100% wool	100% cashmere	Cashmere	50% cotton, 49% polyester, 1% viscose	100% Merino wool	86% co nylon /
Fabric/tactile properties	soft, fine-knit cashmere			In the finest Italian cashmere, this jumper mirrors the look and feel of an athletic pullover		Featuring a lovely ultra-fine texture with a glossy sheen, With anti-pilling processing	soft cot extra w
Fit-related description				Classic Fit	Straight fit knit sweater with a round neckline, long sleeves and ribbed trims	Stylish details include a varying amounts of ribbed knit depending on the area; Great for sporty styles.	Regular body wi silhouet cuffs ar comfort
Model information		The model is 188cm and is wearing size medium	Model is 1m87 / 6'1 ½" and wearing a size M.	Model is 1.85 m and wears a size M	HEIGHT OF MODEL: 189 CM / 6' 2" SIZE: L		
Washing/care information	Hand wash, Dry-clean only		We recommend that you read the care instructions on the label sewn inside this garment	Dry clean	⊞ ✕ ⊟ ⊠	Machine wash cold, gentle cycle	Cold wa Do not the dry tempera necessa
origin		Made in Italy	Made in Italy	Made in Italy			

figure 2.7 Benchmark of some apparel brands

	adidas	LV
	...tton / 12% ...2% spandex	50% Cotton, 50% Wool
	...ton blend for ...armth	
	... fit: a wider ...th a straight ...te, The ribbed ...d hem keep it ...able.	
	...ashing program, ...bleach, Not in ...er, Iron at low ...ature if ...ary	Gentle dry clean，Iron inside out
		Made in Italy

	VARIANT MALIBU	MINISTRY OF SUPPLY	UNMADE	The Girl and the Machine	ZOZO
Material used	Made of a pima cotton and merino wool blend.	49% Extra-fine Australian Wool, 49% Polyester, 2% Lycra®	100% Extra Fine Italian Merino; certified by Woolmark.	100% extra fine merino	100% Merino Wool
Fabric/tactile properties	Soft to the touch and light in weight	Ultra-soft Australian wool plus Lycra is a recipe for comfort in motion, while targeted ventilation keeps you comfortable across a wide temperature range; A layer you can put on in the morning and forget about until the end of the day.		The merino fibre is very fine (19,5 micron) and is therefore very soft to the skin. Wool is naturally anti-bacterial, it doesn't easily smell and dirt simply falls off the fibres.	The Merino Crew is made with a super lightweight, extra fine 100% merino wool that is soft on the skin and extremely versatile; This knit feels smooth against the skin and lightweight enough to wear all year long.
Fit-related Description	It is designed to lay relaxed on the body for a classic look whether you dress it up or down; for easy layering or casual wear.	Fits true to size and hugs the body without feeling tight or constricting, Atlas Sweater is designed to be worn over a dress shirt; Curved back yoke and forward shoulder seam with ribbing for structured shoulder line.	Our classic crew jacquard sweater is designed for a relaxed fit in a mid weight knit.		We deliver your best fit based on the measurements of your unique shape. Customize your fit by adjusting the shoulder and/or the chest to enjoy a slim or loose fit. Or, simply opt for the ZOZO recommended fit.
Model information					
Washing/care information	MACHINE WASHABLE	Machine wash cold. Lay flat to dry. Cool iron if needed.		Our merino has the Woolmark Total Easy Care label and is guaranteed washing machine washable at 40 degrees C	Machine wash cold, permanent press cycle; Do not bleach; Do not tumble dry; Dry flat in shade; Warm iron; Dry clean
origin		Made at Vista Apparel in China			

Online solutions that help people decide sizes

In the previous section "Apparel fit & fit perception" in Chapter 2, it tells that people have different feelings on how they like clothing to fit their bodies. Therefore when developing garment specifications for custom size, it's important to consider both customers' body sizes and their personal preferences or wishes.

To help people decide garment sizes, there have been many different tools used on online apparel shops, such as a smart fit quiz or a size predictor. The goal of this research activity was to learn the perceived usefulness and ease of use of these online solutions from customers' perspectives, so potential opportunities and problems can be considered in the design stage.

Research question
1. What kind of function/interaction/ information works and what doesn't work as effective decision-making support?
2. Do people feel easy to use these tools? Where are the gaps in their knowledge to make decisions?

Method
Three existing online solutions that help people decide sizes were selected to be evaluated as they represent very different types of tool and cover a wide range of key interactions (see figure 2.8, for complete task flows and detailed interfaces, see appendix B). The evaluation was done by doing a task walkthrough with some students. The testing sequences of the three solutions were changed every time and the brand logos on website were hidden, so some disruptive factors can be reduced.

>Participants
Five TU Delft students

>Procedure
The procedure of the activity was as follows:
1. I introduced the research goal and procedure to the participants.
2. Each time before they tested the online solutions, I explained the context that:
a)zozo: Assume that you already have your body measurements input to the system. Based on that, the system recommends a custom-fit specification of the garment for you. You can further adjust the garment sizes according to your preferred fit on different body parts.
b)Fit finder: You find a piece of knitwear you'd like to buy online. To help you select the right size from xxs to xxl, you can use the "fit finder" plug-in by answering a series of fit-related questions.
c)Bivolino: You want to order a shirt made on demand online. In the last step, you need to give some information to get a custom-fit size for your garment.
3. Participants experienced those key interactions (so they skipped the former steps such as registering, searching, measuring body, personalizing the shirt look).
4. They were asked to think aloud during the process.
5. They gave overall comments in the end. To evaluate perceived usefulness, they were asked how confident they feel that the final garment will fit properly; how hard they feel to follow all the steps.
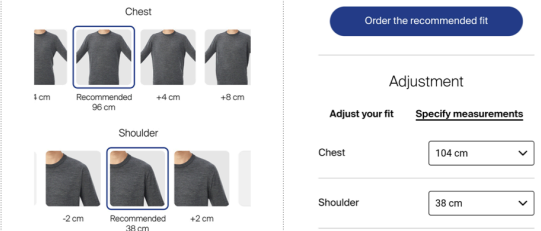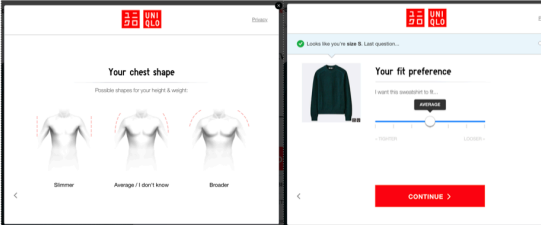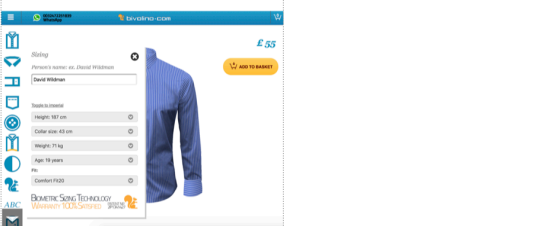
Existing solutions to evaluate	Key interactions	Description	Test with	Interfaces
Garment specifications adjustment based on the recommended fit	- Adding/ subtracting measurements (cm) of the garment	The system recommends a custom-fit specification of the garment. Based on that, customers can further adjust their preferred fit on different body parts. Or, simply opt for the recommended fit.	ZOZO	
Fit quiz based on sizing algorithm	- Indicate one's fit preference with a slider -Indicate one's (subjective) assessment on body shape	The system asks customers a series of question, including basic body information(weight, height, age), how they compare themselves to other people to and past experience in shops, and their fit preference. Customers answer these questions without measuring themselves. A slider is used to indicate their fit preference.	Fit Finder plug-in	
Size prediction	- Input very basic body information to get a predicted size	Customers only need to tell the system their height, collar size, weight, age, and fit preference. The system predicts customers' other body measurements and promises to make a custom-fit shirt based on these data. After that, customers go to check-out directly without seeing the prediction results and their shirt's size.	bivolino	

figure 2.8 Overview of 3 existing online solutions that help decide garment sizes and preferred fit

Test findings

1. Participants wanted to know the exact custom-fit garment size created from their own body measurements. Transparent result is a positive factor to enhance the level of truth.
2. Answering question such as preferred fit could cause confusion because the standard is ambiguous and abstract. People know that fit standard comes different across brands. The textual information of slim/regular/looser fit is neither convincing nor clear to understand.
3. In ZOZO, it allows customers to adjust the garment size themselves, such as "+2cm on shoulder". However, participants didn't feel confident to do that because It's unclear for them how the adjustment will actually influence the body fitting. They tended to go straight for the recommended sizes.
4. Asking very little information from customers raises their doubts in the accuracy of the result. Although size prediction algorithm may reduce the customers' effort invested, they feel a quality lost on custom fit service.

Insights for design

- Indicating one's fit preference is hard because there is no common standards for referencing. There is also a disconnection between "adjustment of garment specifications" and "fit effect on one's own body". So a good design opportunity is to bridge these disconnections in a visualized way.

- Showing transparent data of recommended garment dimensions based on body measurements could enhance customers' truth in the result. In reverse, asking customers very little information or self-assessment questions on body shape could raise their doubts in the accuracy of the result.

Taking body measurements

To make custom-fit garments, a necessary step is to get accurate body measurements from customers. Although new technology such as 3d body scan has been introduced into fashion industry, measuring at home is still the most economic and time-saving method widely used when making an order online. This section listed some measuring methods currently used in online apparel market.

Measuring body dimensions
Customers follow the instructions online to measure their body dimension, and then enter their data to the system.
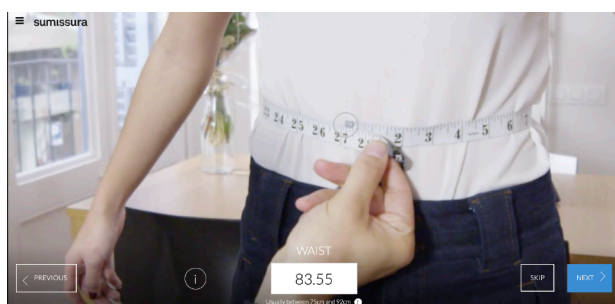
figure 2.9 interfaces of measuring instructions from sumissura

Mobile scanning
Mobile body scan enables consumers to obtain a 3D digital model of their body with smartphone and provides product matching solutions.

One company using this technology is Redthread. They text customers a link after purchase to scan their body.

figure 2.10 redthread uses body scan for best-fit

Another company using this technology is ZOZO. It requires customers to wear a ZOZOSUIT that has more than 350 white dots and takes 12 photos of them (as they stand facing each hour on a clock) and capture where each unique dot is located in space.
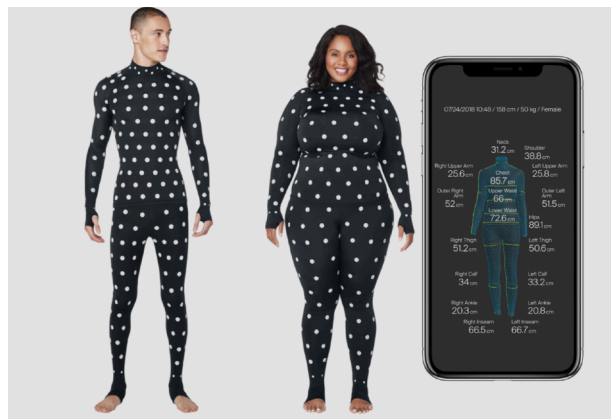
figure 2.11 ZOZOSUIT and ZOZO app

Measuring a garment that fits perfectly
Customers measure a garment that they think fits exactly how they want (or very close). They follow instructions and enter the measurements of the old garment to create custom sizes for a new garment.

figure 2.12 video instructions from propercloth

Technology learning
3D Virtual Fitting

Following the previous section "The application of garment CAD software" which provides a basic introduction of virtual fitting, this section further discusses the key components of this technology based on the learning of a specific software CLO3D, as well as how it can be used in the specific context of visualizing personalized knitwear. CLO3D is a fashion design software program that creates virtual, true-to-life apparel visualization with cutting-edge simulation technologies for the fashion industry. Afterwards it presents a small experiment on how people perceived different properties of virtual knitted fabric created by CLO3D compared with real fabric.

Key components of 3D virtual fitting

Individualized Avatar

An individualized avatar can be understood as a digital model of the customer. To create custom-fit knitwear, some certain body measurements of customers are needed. All these measurements can be assigned to a virtual avatar in CLO3D(see figure 2.13). As CLO avatar editor is powered by thousands of real body scan data, even measurements not assigned will automatically adjust, so an avatar with the most realistic body shape as a customer can be created.
The visualization of an avatar consists of three aspects:
(a) a 3D model representing the body shape
(b) Skin textures mapped on body surface
(c) A skeleton that forms the basis for different poses

| Chest circumference | Length neck to chest | Waist circumference | Length neck to waist |
| Shoulder width | Arm length | Wrist circumference | Biceps circumference |
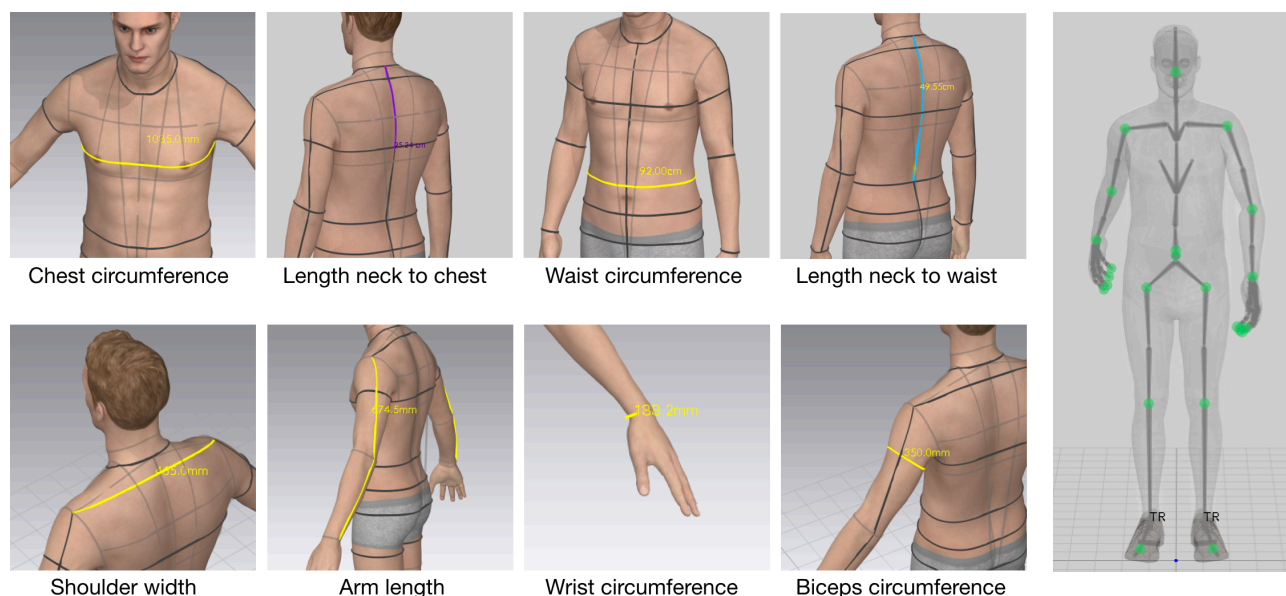
figure 2.13 Key body measurements of an individualized avatar and his skeleton

Garment creation and simulation

In real life the company Personalized Knitwear uses the traditional 2D pattern approach to make knitwear: first make 4 patterns (front vest, back vest, two sleeves), then seam them into a whole piece. The virtual garment can be created in CLO3D by following a similar process: drawing 2D patterns, editing sewing lines, applying physical parameters of the fabric and knitting texture to the patterns. Then a realistic visualization of the 3D garment can be realized (see figure 2.14).

To draw 2D patterns for custom-fit knitwear, the current solution of the company is to add certain extra length to body measurements (see figure 2.15). The whole garment length is about 16cm longer than length from neck to waist. The chest circumference of the garment is 10cm larger than that of the real body. The sleeve length is same as the arm length. The sleeve's fullest circumference is 10cm larger than bicep circumference.

To sum up, the visualization of a virtual garment consists of three aspects:
a) 2D patterns outlines
b) Sewing lines
c) Fabric properties and textures

figure 2.14 3D garment (left) created from 2D patterns (right)

figure 2.15 principles of 2D patterns design

Body measurements

a=chest circumference
b= shoulder
c= neck to chest
d= neck to waist
e=arm lengthen
f= bicep circumference
g= wrist circumference

Size and fitting

First, with the individualized avatar and the virtual knitwear, the software can show a visualization of how the knitwear fitted onto the individualized avatar (see figure 2.16).

figure 2.16 A virtual model wearing the knitwear made with his measurements

Second, the software can also show an instant visualization of how the adjustments on garment specifications will actually be reflected on body fitting. In CLO3D, a size grading on different body areas can be created by editing corresponding points of 2D patterns, and the 3D effects can be simulated instantly(see figure 2.17). The figure shows an example of how adjustments on shoulder and total lengthen are reflected on body fitting.
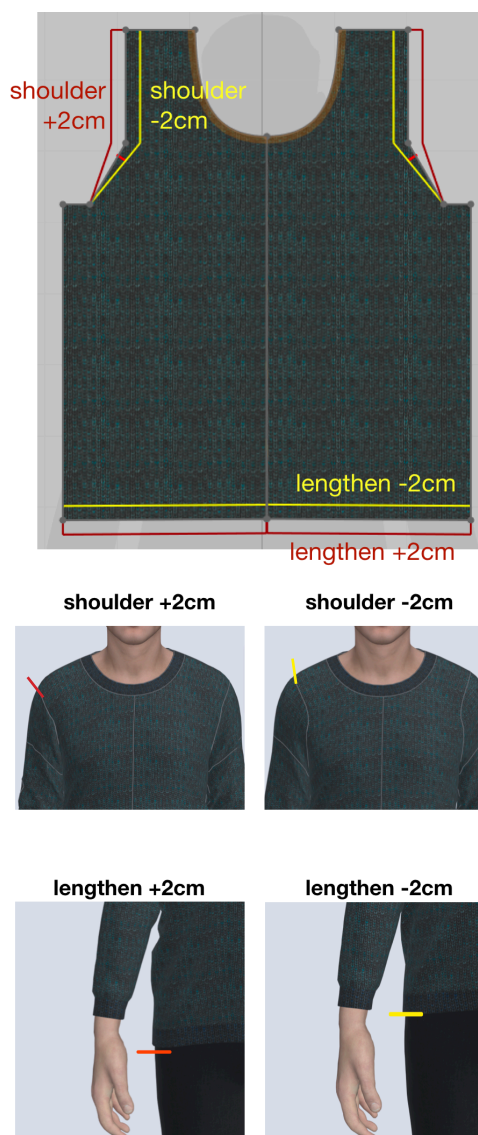
figure 2.17 Creating grading of 2D patterns (left), 3D simulation effect (right)

Interactivity

As explained in the previous section "Customer experience in 3D virtual try-on", interactive 3D technologies can add both functional and experiential values to the virtual fitting. Several types of interactive operations are shown as below, which are related to how the user control the scene and modify viewing settings. The design could provide these rich interactivities to enhance customers' shopping enjoyment.

figure 2.18 Zooming in details and rotating the scene

figure 2.19 Changing surroundings

figure 2.20 Changing poses

Experiment of virtual fabric perception

Study objective

To get a better understanding of how well the virtual knitwear could communicate its material properties, a small experiment was done to learn people's perception on both the real knit fabric and the simulated one created by CLO3D.

>Research Question:

1. What expectations do people form when they see the 3D virtual fabric on screen?
2. Does it meet their expectation after checking the real fabric? Where are the differences?
3. Does the color of the fabric influence people's visual perception on tactile attributes?

Virtual fabric making

The original fabric swatches were provided by the company Personalized Knitwear (see figure 2.21). The virtual fabric swatch was created in the software CLO3D by applying physical properties and knit textures to the simulated fabric. Some physical properties were acquired by measuring and calculating the real fabric directly, such as thickness, density. Some were estimated by constantly comparing the real and virtual draping in software, such as bending, buckling (see figure 2.22). The knit textures were digitized with the scan of the real fabrics and was processed into seamless textures in photoshop afterwards (see figure 2.23).

figure 2.21 Original fabric swatches provided by the company Personalized Knitwear
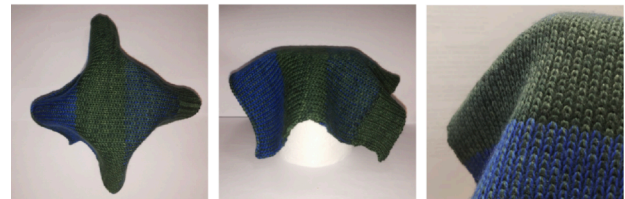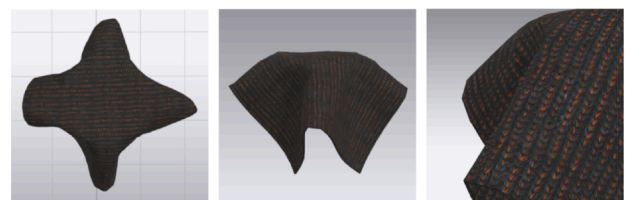
figure 2.22 Comparison of the drape of real and virtual fabric
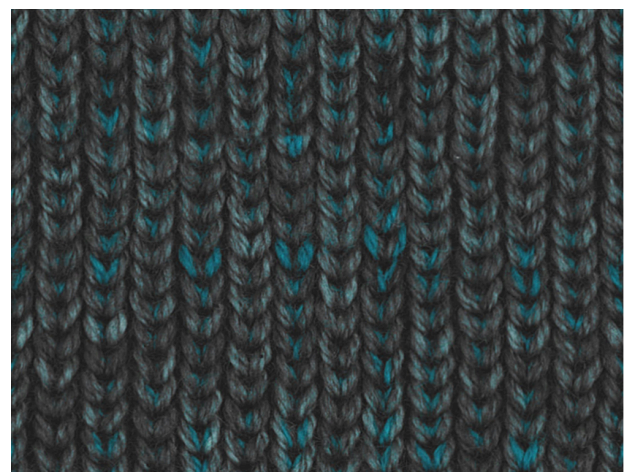
figure 2.23 Seamless texture

Method

A sensory evaluation on fabric properties was done with a 10-point bipolar scale (see figure 2.24). The selection of sensory criteria were based on important tactile attributes for fine knitted fabrics proposed by Wang, Mahar and Postle (2013), and handle of weft-knitted fabrics defined by Chen, Barker, Smith & Scruggs (1992). These properties are crucial to make one fabric preferable or selected over another.

Participants first saw the virtual fabric on screen and then saw and touched the real one. They were asked to rate their perceptions on fabric properties both times. There were four images presented together to participants (see figure 2.25). Three of them showed the fabric with different colors draping on a sphere, and the last image showed the fabric with a pen beside as reference. For complete information about the experiment, see appendix C.

>Participants

10 random people in DOK Center (a library in Delft) were interviewed, 7 male and 3 female, aged from 18 to 61. All of them self-assessed that they had shallow knowledge or no knowledge about knitting.

figure 2.25 Images of virtual fabrics shown to participants

figure 2.26 Participants doing the test

Surface Property

| Clean | 1 2 3 4 5 6 7 8 9 10 | Hairy |
| Smooth | 1 2 3 4 5 6 7 8 9 10 | Rough |

Flexural Property

| Soft | 1 2 3 4 5 6 7 8 9 10 | Hard |
| Loose | 1 2 3 4 5 6 7 8 9 10 | Tight |

Perceived Temperature

| Cool | 1 2 3 4 5 6 7 8 9 10 | Warm |

Bulk Property

| Light | 1 2 3 4 5 6 7 8 9 10 | Heavy |
| Thin | 1 2 3 4 5 6 7 8 9 10 | Thick |

Overall Quality

| Poor | 1 2 3 4 5 6 7 8 9 10 | Excellent |

figure 2.24 Bipolar scale of sensory fabric properties

Results

Participants' evaluation on sensory properties of both virtual and real fabrics were analyzed, as well as the difference between the two samples (see figure 2.27). With "1" the fabric is most associated with the term on left, with "10" the fabric is most associated with the term on the right.

1. What expectations do people form when they see the 3D simulated knitted fabric on screen?

On an average, participants expected that the fabric is of good quality, clean, smooth, heavy and thick from seeing the images on screen. The result didn't show obvious tendencies between soft/hard, loose/tight, but it was averagely thought to be a little bit hard and loose. The perceived temperature varies considerably between individuals.

2. Does it meet their expectation after checking the real fabric? Where are the differences?

The evaluation on the overall quality remained almost the same with a slight decrease from 7.7 to 7.5. The perception on surface properties (cleanness and smoothness) was most accurate.

The biggest difference lies in the perception on bulk properties. Participants felt the real fabric is lighter(-2.5) and thinner(-2.4) than they expected. The average scores of heaviness and thickness were 6.5 and 6.6 before. After touching the real fabric, the average scores fell to 4.0 and 4.2. It was mentioned that thickness is an important attribute to consider buying knitwear because it's very related to which season to wear the knitwear.

The second biggest difference lies in the perception of softness. Participants felt the real fabric is softer(-1.8) than they expected. The perception on this property turned from a bit hard(6.0) to soft(4.2). "Soft" is a good attribute of 100% fine merino, so it will be a pity if customers understand the other way around.

3. Does the color of the fabric influence people's visual perception on tactile attributes?

Four of the ten participants thought different colors influence their perceptions on fabric properties. In those cases, the color had most influence on feelings of surface properties, and didn't seem to affect feelings on any bulk properties. The lighter color tends to make the fabric look more hairy and soft. The darker color makes the fabric looks more clean and smooth.

figure 2.27 Ratings for sensory properties of virtual and real fabrics

Summary

- How people understand the description words is quite different. Their perception on the same property could varies considerably between individuals.

- The real fabric was thought thinner, lighter and softer than what was expected from the virtual one. Cleanness and smoothness were understood well. There still exists some limitations of using the virtual fabric to communicate its physical properties. Other information such as real pictures and textual description will still be necessary for customers.

- The influence of color was not a general case. In some cases, it impacted the feelings on surface and flexural properties, especially cleanness and softness. Perception on thickness and heaviness didn't seem to be influenced.

DESIGN BRIEF

FROM RESEARCH TO DESIGN

Design Goal

With a review of the former research, it provides many insights to see what could be problems, challenges and opportunities for the context of online shopping of personalized garments. These findings are summarized and transformed into the explicit design goal.

Concluding from the research findings, one main problem is the lack of sensory inputs for product examination in online environment, which is especially important for apparel products. The inconfidence that the garment will fit properly is a common problem encountered by e-shoppers. People need both visual and tactile feedback from wearing the garment to evaluate its fit, but this experience is degraded when they go online shopping. Instead of physically trying on the garment, customers need an alternative sensory experience of evaluating clothing fit online.

Another main problem is the perceived complexity and uncertainty of making choices on personalized garments. To personalize a garment is kind of a co-design process with customers, so the final design of the garment is largely dependent on their decisions. However, there could be knowledge gaps or choice uncertainties in decision making, because most customers are non-expert users with a limited understanding of knitwear design as well as their real needs. So before letting them co-design the knitwear, first it's necessary to define all the options well and enable them to easily and clearly understand what every choice means.

The other main problem is to translate customers' body sizes and personal fit requirements into garment sizes. People are with different bodies and have different preferences for how they like clothing to fit their bodies. On one hand, getting the size right requires customer to take their body measurements correctly. One the other hand, understanding their preferred fit is also needed

to meet their personal wishes. However, it's hard to ask customers to indicate their preference on sizes without a clear standard to compare with. There are many disconnections between "garment sizes" and "fit effect on one's own body".

Then the research also investigates the technology of 3D virtual fitting as a potential solution. This technology is able to instantly simulate the drape of clothing onto avatars. Its functional and hedonic role for online apparel shopping is confirmed by relevant literature. In addition, the learning of the software CLO3D gives confidence that the visualization of knitwear is achievable, as well as the simulation of how the knitwear fits to different human body models. The size differences reflected on body fitting are perceivable and distinguishable.

To perform the design more explicitly, the design goal is formulated that:

"To design a website that enables customers to customize and order knitwear made to their measurements, in all possible looks, sizes and fits. Include the use of 3D virtual fitting in the website to boost customer confidence in evaluating clothing fit online and shopping enjoyment. In the end deliver with the real garment that achieves their satisfaction."

Design Framework

The design goal is supported with a framework of the website structure, which describes how the desired experience would be achieved on the end user's side.

The framework of the website structure describes what elements constitute the website with four layers (see figure 3.1). Each layer gives rules to how the website should be built. It is further explained by a layout diagram of the main page of the website, explaining how each layer should be built in by design (see figure 3.2).

First on the outside layer is the base of the whole website, all the interfaces should reach good usability and have a beautiful and appropriate visual style fitting the company image.

On the second layer is the website content, which should communicate all the necessary information to customers, including the information about the product, the company and how the ordering process works.

Thirdly, within the website content there is a knitwear configurator. It builds a step-by-step process to enable customers to configure their personalized garments, and provides relevant information to support each step. In this case the three steps are choosing neckline, color, size.

Last but not least, the core layer is a 3D virtual fitting room embedded in the website. It introduces the use of virtual fitting technology in the online environment, showing an instant visualization of the future garment fitted onto customers' body. It should play an effective role of providing proxy sensory experiences that can serve as a surrogate for physical try-on.
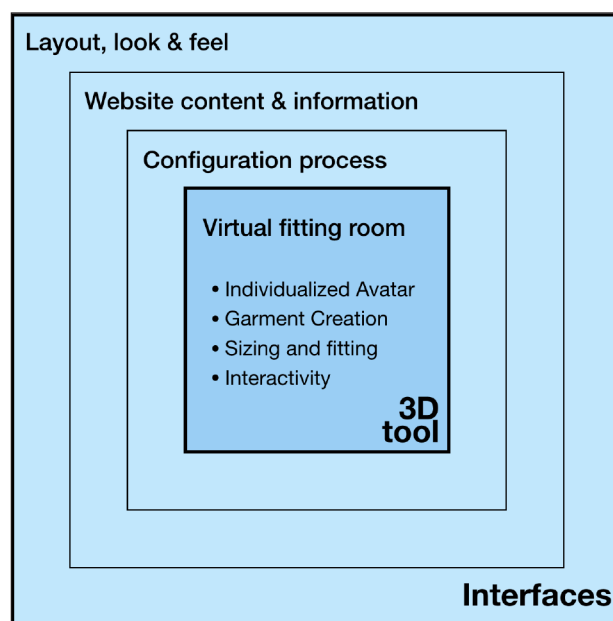
figure 3.1 Website framework
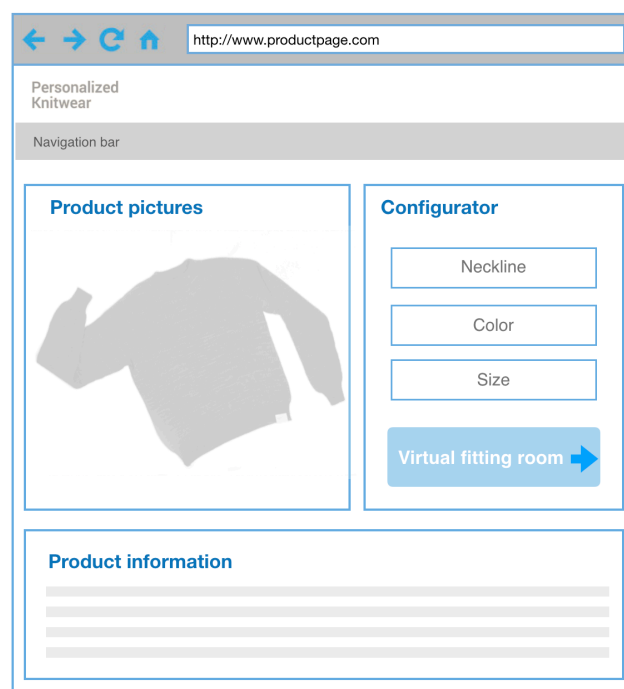
figure 3.2 Layout diagram

Design Requirements

The insightful knowledge gained from the research is incorporated and transformed into concrete design requirements for the specific context of online shopping of personalized knitwear. As shown in the table below, the first column lists all the design requirements; the second column shows which website part is related to every requirement; the third column refers to which research part supports every requirement.

The list of the requirements is used as a guideline for developing the design, and as a criteria for evaluating the final concept.

	General requirements	Related elements	Backup Research
1.1	The website should reach good usability.	All	
1.2	The website should have an appropriate visual style.	All	

	Functional requirements	Related elements	Backup Research
2.1	The website should tell what material is used for the knitwear, how it feels and performs, instructions for wash and care. Also provide fit-related information and fit tips on the specific garment.	Website infomation	Industry research "Online knitwear retailing"
2.2	The website should show both close-ups of knit stitches and the pictures of knitwear from different sides.	Website infomation	Industry research "Online knitwear retailing"
2.3	The configuration process should provide relevant knowledge/expertise for decision-making in each step.	Configuration process	Literature research "Online personalization service design"
2.4	The configuration process should allow for readjusting and navigating back and forth among its each step.	Configuration process	Literature research "Online personalization service design"
2.5	The website should provide an effective guide of taking body measurements to get accurate data from customers.	Configuration process	Industry research "Measuring body at home"
2.6	The website should provide transparent data of the recommended garment dimensions that are calculated from personal body measurements.	Configuration process	Industry research " Online solutions that help people decide sizes"
2.7	The website should feed personal fit preference into the decision of sizes.	Configuration process	Literature research "Apparel fit & fit perception"
2.8	The virtual fitting room should use a digital avatar representing individual customer and show how the knitwear fitted onto the avatar.	Virtual fitting	Literature research "Apparel fit & fit perception" ; Technology learning
2.9	The virtual garment should simulate realistic material properties and knitted texture.	Virtual fitting	Technology learning

2.10	The virtual fitting room should show how every change on garment sizes is actually reflected on body fitting.	Virtual fitting	Industry research " Online solutions that help people decide sizes"; Technology learning
2.11	The virtual fitting room should include rich interactivity with the 3D scene.	Virtual fitting	Literature research "Customer experience in 3D virtual try-on"; Technology learning

	Experiential requirements	Related elements	Backup Research
3.1	Customers are willing to go through the configuration process, able to make choices confidently, without burden of choice or preference uncertainty.	Configuration process	Literature research "Online personalization service design"; Industry research " Online solutions that help people decide sizes"
3.2	Customers have higher confidence in evaluating fit of clothing online from using virtual fitting.	Virtual fitting	Technology learning; Literature research "Customer experience in 3D virtual try-on"
3.3	Customers have higher shopping enjoyment and engagement from using virtual fitting.	Virtual fitting	Literature research "Customer experience in 3D virtual try-on"
3.4	Customers' needs are satisfied with the result of their personalized knitwear created online.	All	
3.5	Customers who place an order are satisfied with the actual knitwear they receive in real life	All	

CONCEPT DEVELOPMENT

User flow

Based on the design goal and the framework proposed in the last chapter, a user flow was visualized to show the path taken by customers on the website (see figure 4.1). The user flow takes them from their entry point through a set of steps towards a successful purchase. For a new customer, the main action steps he needs to finish to order a personalized garment are: browse the website; choose a style; choose colors; decide sizes; add to cart. To decide sizes, the website provides two options: Create custom sizes or Use standard sizes. The first one requires customers to enter their body measurements, choose preferred fit and try virtual fitting. The second one provides them a quicker way to choose S/M/L/XL directly with a size chart.

The steps illustrated with blue boxes in figure 4.1 are the main focus of this project. It's sure that where people know the company and how they experience payment and shipping process will have influence on the entire customer journey, but in current stage these factors are not in the scope of this project.
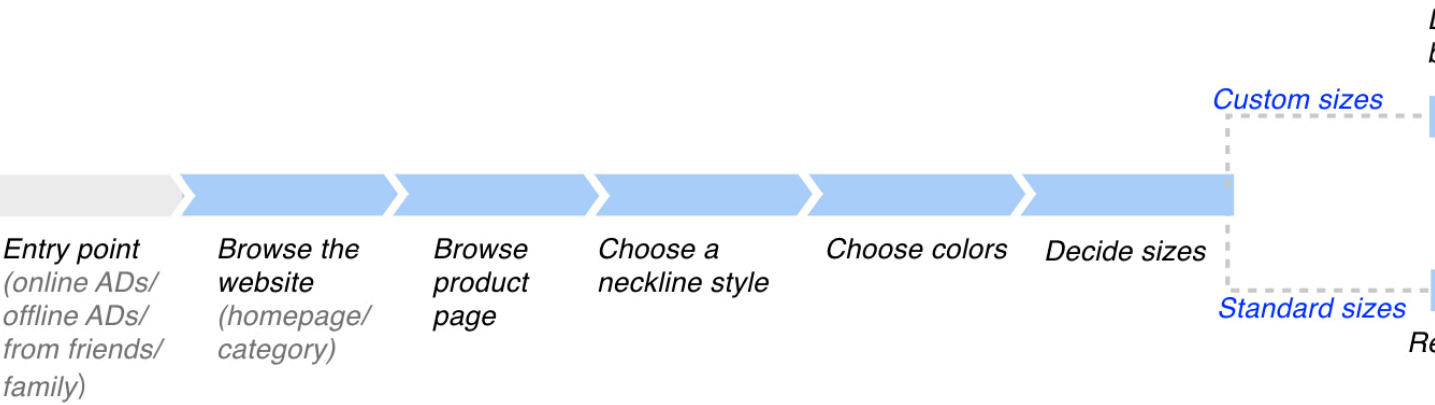
figure 4.1 User flow of making a purchase

Do and enter
body measures

Choose fit
preference

See virtual
fitting effect

Add to
chart

Check
out

Pay

Wait for
production
and Delivery

Receive
the
knitwear

Read size chart   Choose a size
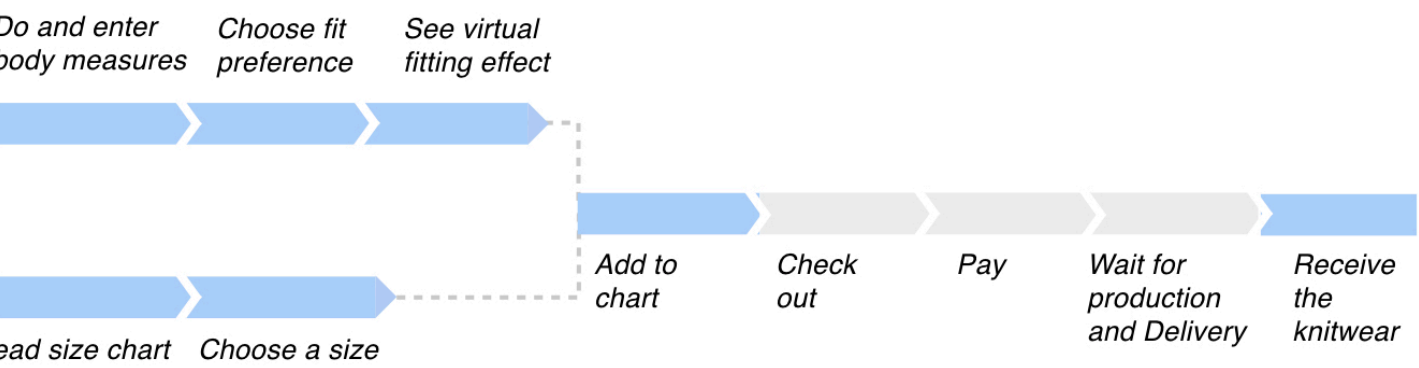
Design Process

A round of research and design activities were done to enhance the design phase, which included prototype-making, rapid-evaluating and decision-making. Some key interfaces were first developed to investigate how the design works. The user flow was divided into small parts to be tested, so the design effectiveness of each part can be evaluated respectively. In that way, it's easier to find out which UI components are problematic/liked and accurately address potential problems related to customer experience, interaction and usability.

In this section three test activities are discussed by describing (a) the objectives of the test and what questions were to be answered, (b) the interfaces developed for the test, (c)the activities that were done and (d) a discussion of the results, what was learned from them and (e) what were the inputs for the final design.

Activity I. Product Page
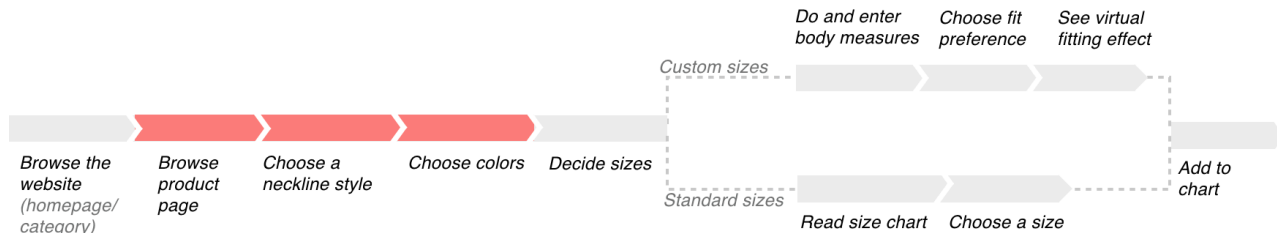
Test Objectives

> Test what

What was tested in the first activity was the product page excluding the sizing part. The raw information of the page were provided by the company. The steps marked in red were the part of experience evaluated.

> Why

The objective of the test was to assess how easily customers can connect all the information with the product and how clear can they understand the personalization options (style and color). So the unclear website components can be found and adjusted; the information content can be improved.

>Questions
- Do customers get sufficient information of the product? What is still missing?
- What impression do they have on the product based on the pictures/information presented on the website?
- Can they understand the personalization options of style and color?

The design of interfaces and interactions

The evaluation object is the interface of the product page, on which customers can browse product information and configure style & color. (see figure 4.2)

The activity

The test was done with six fellow students of IO. Testing with them was an effective and efficient way to help refine the design in an early design phase. Although they were not the first target users, they were easier to access and their feedbacks were also valuable because the website itself was designed for everyone. The definition of target group was more from a market perspective.

The activity followed these steps:
1. I introduced the website and test objectives.
2. I explained the test scenario that they are on a product page of a website selling personalized knitwear, and asked them to leave some practical information out of consideration.

Tasks	Look into the garment in details and select its style and color
Assumption of the scenario	1. Leave practical information out of consideration, such as terms and condition, payment, guarantee. Only focus on product information 2. Leave garment size out of consideration

3. Participants tried the prototype.
4. Participant graded subjective measures in questionnaires and answered some interview questions after the test. (see questionnaire in appendix D)

figure 4.3 A student was testing the product page

figure 4.2 interface of the product page

1. Picture area

Picture area shows real photos of the knitwear. The picture will be magnified at where the mouse is over, to show details of the knitwear and its stitch.
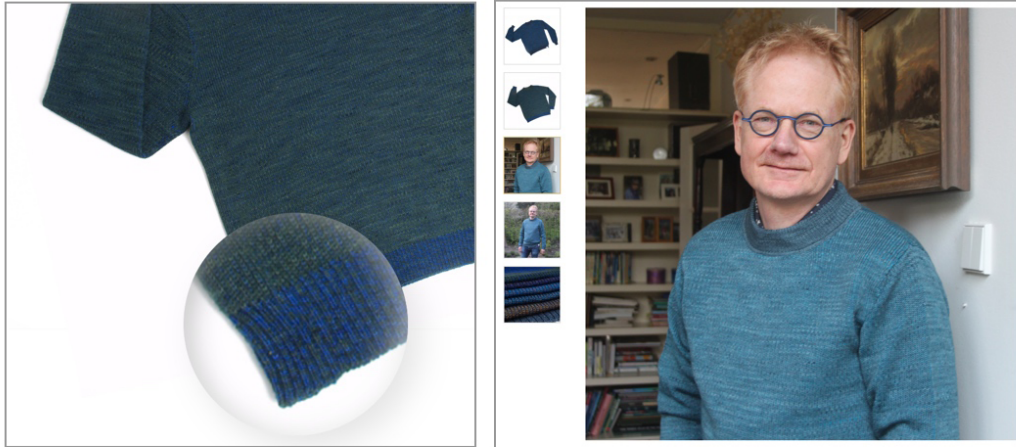
2. Style

Choose either crew or v-neck

3. Color

Choose from seven color options or create a new one. When an option is selected, its color name will show on the interface, and the picture area will show the picture of the selected fabric. When you want to create a new color combination, you choose two color from an color palette.
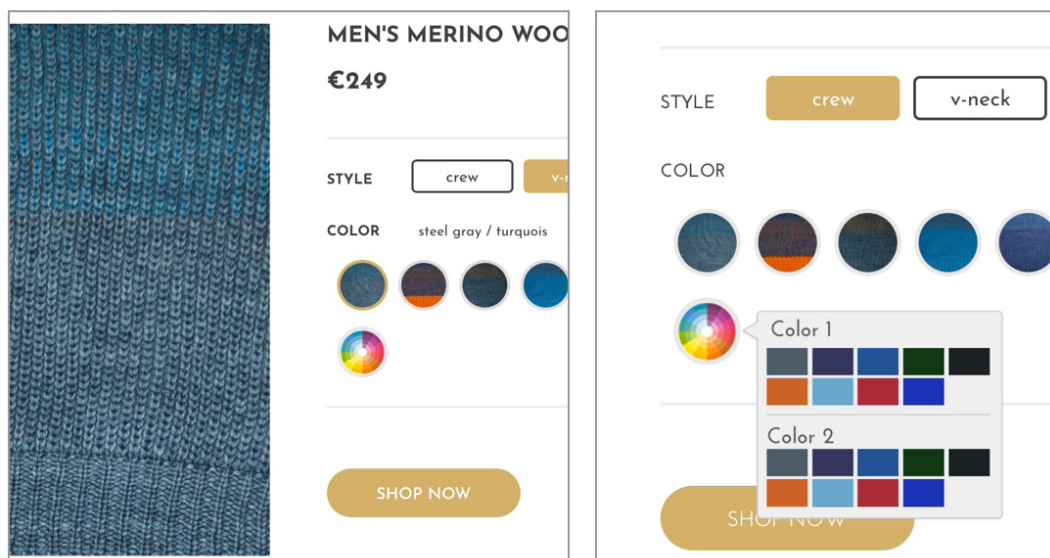
4. Information

Textual description of the knitwear and the design story behind

Discussion of results
> Neckline
It was easy to understand the two options of crew and v-neck, but the photo of a v-neck was missing, which participants thought very necessary.

> Color
The two garment samples shown were Navy blue+Aqua and green+blue (see figure 4.4), some participants thought the garment has a great color richness but didn't realize the stitch uses two colors. The two yarns were interwoven together and the color of a single yarn was slightly uneven, so it was hard to distinguish two contrasting colors if you look at the garment from a certain distance. This caused confusion when they were asked to choose a color combination of two colors.
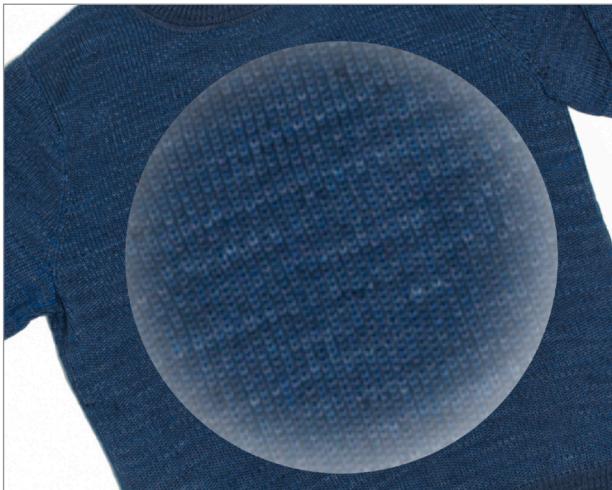
figure 4.4(a) Navy blue+Aqua knitwear

figure 4.4(b) Green+blue knitwear

Photos of swatches were not clear enough for participants. It raised feelings of uncertainty on making decisions. They would prefer to see pictures of a complete garment with the selected color.
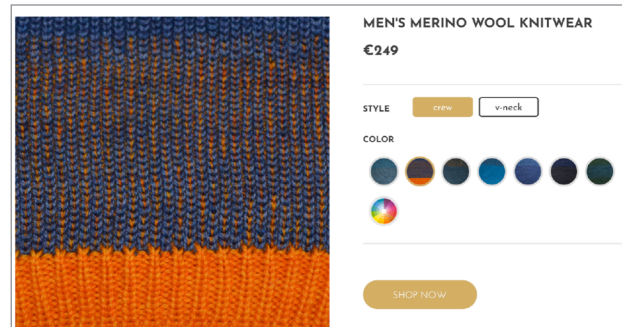
figure 4.4(c) Photos of swatches

> Text information
Most textual description were just overlooked. Participants didn't feel like reading so much plain text, which reduced their patience at first. One participant said he would just quickly browse the key points.

Hand-dyed yarn was an interesting attribute for someone. They thought a picture of the production process or environment would be more convincing than textual explanation.

Overall impression
- From participants feedback about their overall impression on the webpage, the good thing was that they thought the product was of high quality. The downside was that the information given were not sufficient, especially the lack of photos. Most participants (5/6) thought they didn't get enough information of the knitwear.(see responses in appendix D)

Inputs for design

First, more pictures and information were needed. I made a list of what was good to have on the website and communicated it with the company. They took some new photos and provided new texts to me, except the photos of the whole garment with different colors. At the moment it was impossible to knit all the samples of each color.

> Pictures
1. Photos of different neck style
2. Photos of garments with different colors
3. Dyeing process / fabric
4. warehouse / studio environment

> Text
1. Explanation of ordering process (produced after purchase)
2. company introduction/background
3. Fabric information

Second, UI elements were improved to fix the found problems of misunderstandings.

Figure 4.5 shows what was updated
1. added "Step 1,2,3 in title" to tell people where to start
2. added neckline drawings for better visual effects
3. changed the small icons of colors to enhance understanding on that the stitch uses two contrasting colors
4. deleted the option of making a new color combination
5. added text explanation of color on pictures

figure 4.5 Updates of UI elements

Activity II. Deciding the garment sizes

Custom sizes

Do and enter body measures · Choose fit preference · See virtual fitting effect

Browse product page · Choose a neckline style · Choose colors · Decide sizes

Standard sizes

Read size chart · Choose a size

Add to chart

Test Objectives

>Test what

What was tested in the second activity was the process of deciding the garment's sizes. The steps marked in red were the part of experience evaluated.

>Why

The first objective of the test was to make a design decision on what kind of choices about the size should be provided to customers. To create a custom size, both customers body measurements and fit requirements should be taken into account. Therefore it's important to know whether customers would like to spend the time and effort to take body measurements, and whether they have further needs on editing more details of the garment sizes.

The second objective of the test was to learn how the virtual fitting works as a supporting tool to help customers evaluate garment fit. From former research, it is discussed that virtual fitting has perceived usefulness and entertainment values, but how it would be experienced by customers in this context need to be further investigated.

>Questions

- Are customers willing to take time to do body measurements? Would they prefer to create a custom-fit size or use a standard size?
- Is it necessary to let customers freely change size details of the garment?
- Is the tool of 3D virtual fitting able to help participants learn more about the product?
- What kind of interaction with the virtual scene do they think useful for evaluating the fit of the knitwear?

The design of interfaces and interactions

The evaluation objects were the interfaces of size setting and virtual fitting (see figure 4.6 & 4.7).

The activity

>Participants

7 design students in total, 6 of them took the second part of virtual fitting

>Procedure

1. I introduced the website and test objectives.
2. Participants browsed the website first to know about the product.
3. They answered an initial question: Do they prefer to make body measurements to create a custom size or choose from standard sizes?
   (a) If they would like to get a custom-fit size, they continued the test
   (b) If they would prefer to choose a standard size, the test ended.
4. If they continued, I explained the scenario that they need to decide the size of the garment and experience virtual fitting. They could assume that the body measurements had already been entered into the system.

Tasks	Decide the size of the garment and experience virtual fitting
Assumption of the scenario	1. Have the body measurements entered into the system already 2. The virtual model has the same body size with them

5. They interacted with the interface and talked about their opinions.
6. They tried virtual fitting and different interactions with the virtual avatar/scene.
7. They filled a questionnaire after the test. (see appendix E)
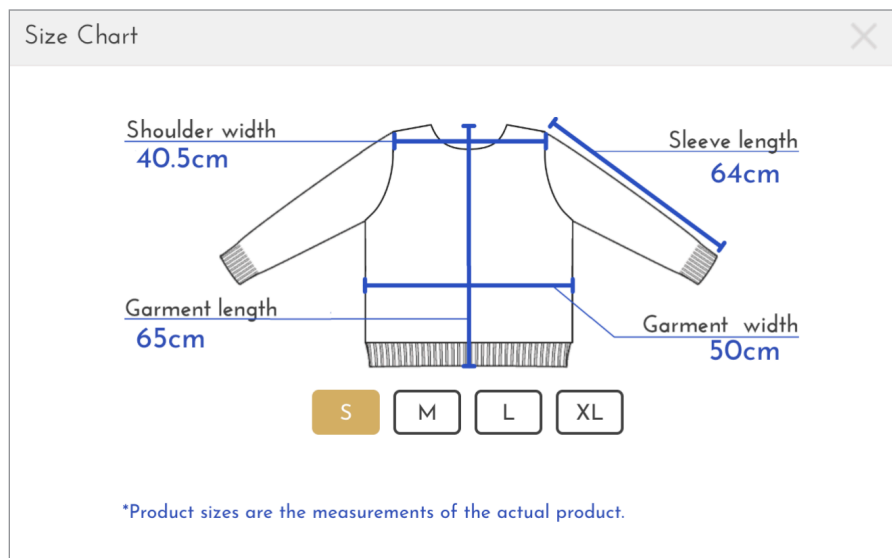
figure 4.6 (a) interfaces of standard size chart
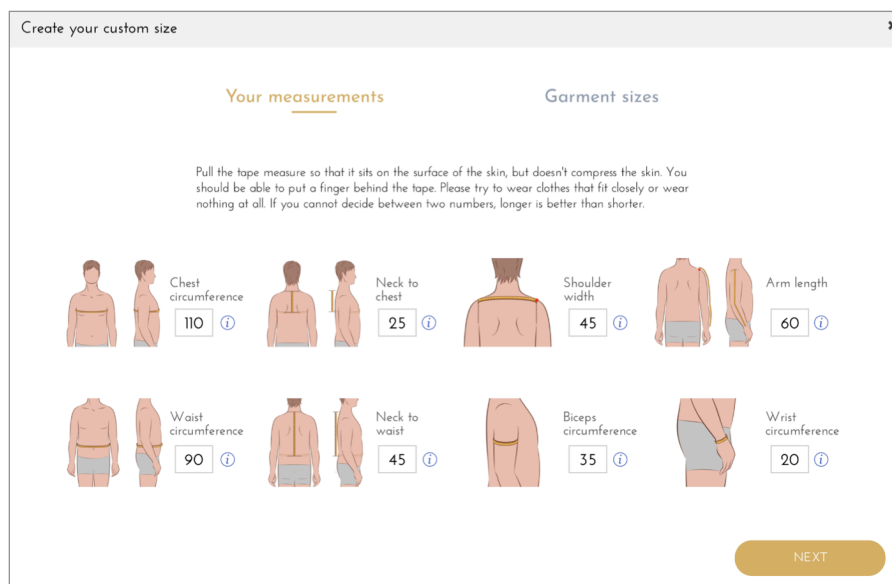
figure 4.6 (b) interfaces of entering body measures before getting started with customized sizes

Create your custom size

YOUR MEASUREMENTS   Jimmy's measurements 19/04/2019 ♦

We generate the custom size of the knitwear based on your body measurements. You can make further adjustments to your liking.

GARMENT SIZE   👔 3D try on>

1 Preferred fit   tight fit   regular   loose fit

Adjust your fit

3
Shoulder width
− 48cm +

Sleeve width
− 22cm +

Garment width
− 60cm +

Sleeve lengthen
− 58cm +

Garment lengthen
− 66cm +

2

1. Fit preference
Choose tight/regular/loose fit according to personal preference.

2. Virtual fitting
A picture will show what tight/regular/loose fit looks on body

3. Size details
The final garment size is transparent. Any size specifications marked in the picture can be adjusted freely.

Shoulder width
− 50cm +

Sleeve width
− 24cm +
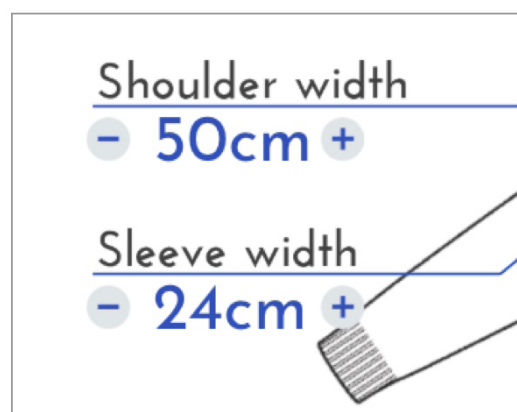
figure 4.7 interfaces of setting customized sizes

Discussion of results
> Willingness to provide body measurements
Six of seven participants were interested in adding body measurements to get a custom-fit size. One participant didn't show interest because he thought standard sizes usually met his demands easily. In addition, considering the type of the garment was knitwear, he was less demanding.
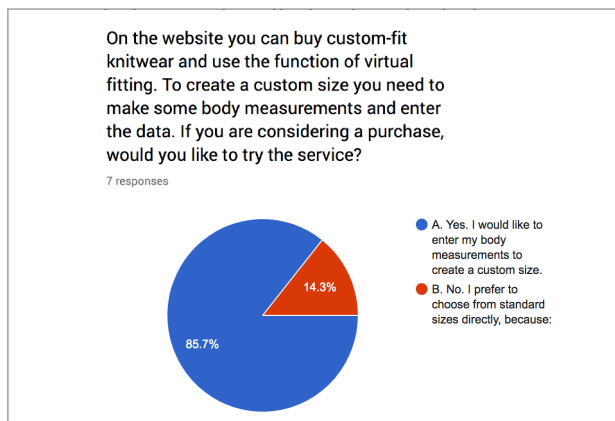
Some quotes from interview:
"I will use the function if I buy from this website. Otherwise I just go to a regular clothing store."

"If the price is the same, why not"

"I think entering body measurements is more direct and easier than choosing from M/L/ XL with a size chart"

"This is useful for me. I am very tall and a lot of clothes with standard size are always too wide for me."

Although most participants answered that they would like to make body measurements, it should be taken into account that it was just a hypothetical question. In real situations, those who say they would like to try may not do it in the end.

> Size details
On the interface, garment size details can be adjusted freely, but only "preferred fit" was thought necessary by all participants. Three of six participants chose "loose fit", and the other three chose "regular fit". They didn't adjust the size details in the test. Making size details adjustable was intended to give customers more freedom, but instead,

it caused some hesitations and made the process more complicated. Some quotes from interview:
"I won't change the data if the system calculates it from my body measurements. I believe it more than myself."

"I think people might get afraid by making these decisions in the chart, but professional customers might need it."

" I might slightly tune the number. I will worry messing the clothes model up if I adjust the number, in the end getting a weird clothes."

> Virtual fitting
From the test feedback (see detailed responses in appendix E), different participants had different opinions on which interactions were most useful. "Changing the poses" and "Rotating the avatar" were thought useful by almost all the participants. "Changing background image" was useful only for one.

The use of virtual fitting did have a role to help participants learn more about the product. It had stronger effects of helping them evaluate the size and the look, but lower effects of helping them learn about the material properties and tactile feelings. The results still had a lot of limitations because the virtual avatar was not created with participants' actual body sizes.

Inputs for design
After this activity, I better understood people's attitudes towards customized sizes and confirmed the perceived usefulness of virtual fitting. Some design decisions were made based on the findings

1. Keep the two options of customized sizes and standard sizes

2. Limit the freedom to adjust sizes details of the garment. Only provide the option of preferred fit.

3. Without regard to technical difficulties, all the rich interactions with the virtual scene should be applied in the design: rotating, zooming in, changing poses, watching virtual animations

Activity III. DIY Measurements

Custom sizes — Do and enter body measures · Choose fit preference · See virtual fitting effect

Browse product page · Choose a neckline style · Choose colors · Decide sizes

Standard sizes — Read size chart · Choose a size

Add to chart
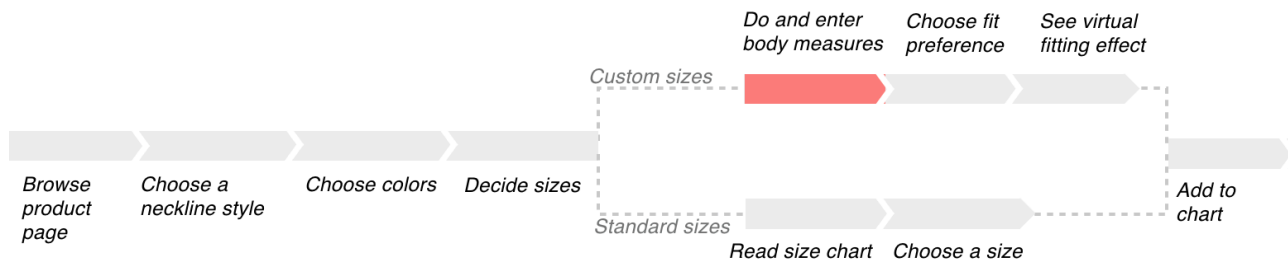
Test Objectives

>Test what

What was tested in the third activity was the instruction of making body measurements. The step marked in red was the part of experience evaluated.

>Why

To provide the function of virtual fitting, a necessary step before is to get customers' body measurements. A good instruction is crucial to guide customers do the measurements because the accuracy of results is a prerequisite for creating custom size and virtual fitting.

For the knitwear model in this project, there was a list of eight measurements required to achieve a best result of the size. The objective of the test was to evaluate the clarity of the instruction and its effectiveness of the instruction in guiding customers to get accurate body measurements, also to evaluate the ease of the task and identify possible difficulties or barriers, so the design of the instruction can be improved.

>Questions

- Is the instruction clear for customers?
- Can they finish all the measurements themselves or need other people to help? Which one is easy/difficult to do?
- Can they follow the instruction correctly to get accurate results?

Test materials

The evaluation object in this test was the measuring instruction given to customers (see in figure 4.10). There were two versions of model at first, slim and normal (see figure 4.8). In the end the normal one was used as it suits most people and the first one goes too much into a beach-ready body.

The activity

>Participants

Four male students with different body types, from slim to overweight, were recruited to take the test. They attended the test in pairs, so there were two pairs in total.

>Metrics

a. Comparison of self-reported and real measurements taken by me
b. Questionnaire on the task experience

>Procedure

1. I introduced the project background and test objectives.
2. I explained the test scenario that they need to make body measurements for a custom-fit garment.

Goal	Make body measurements required by the instruction
Assumption	1. have a tape at home 2. have someone at home to give a hand
Steps	1. Read instructions on laptop 2. Make body measurements 3. Ask the other participant for help when he cannot do it himself 4. Enter the data on laptop

3. They finished the task in turns. They could either do it themselves or ask the other participant for help. (see figure 4.9)
4. I took their measurements after the test.
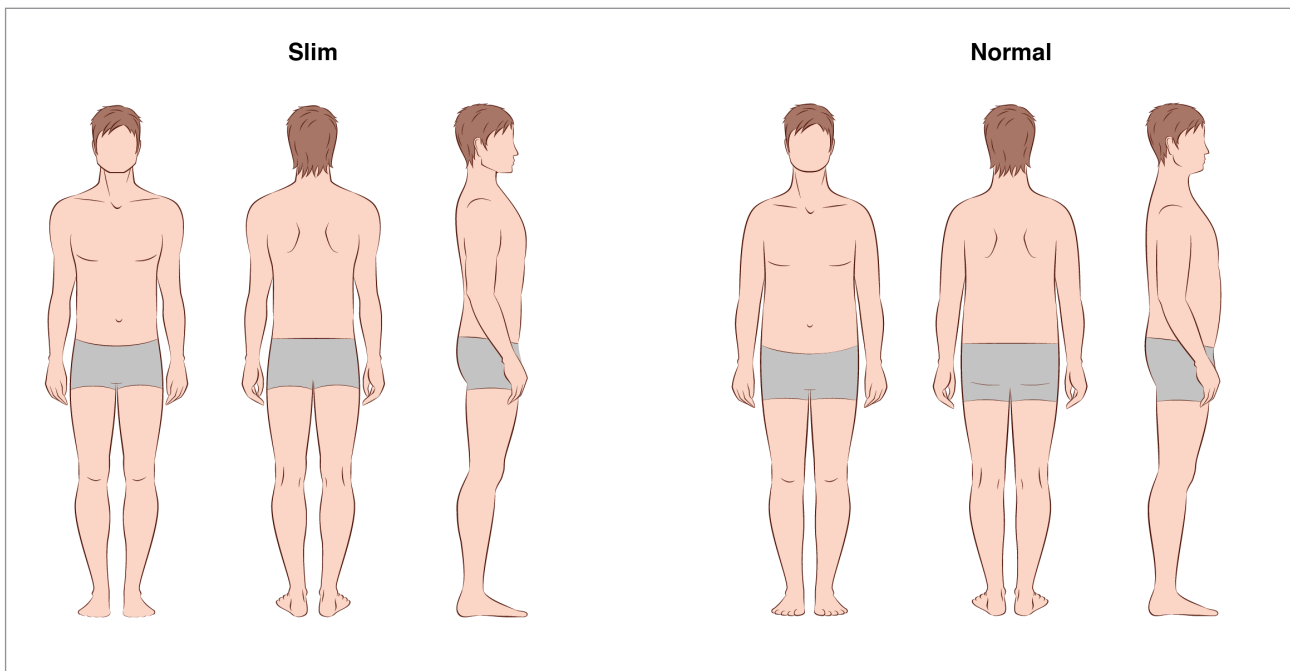
figure 4.8 two model versions
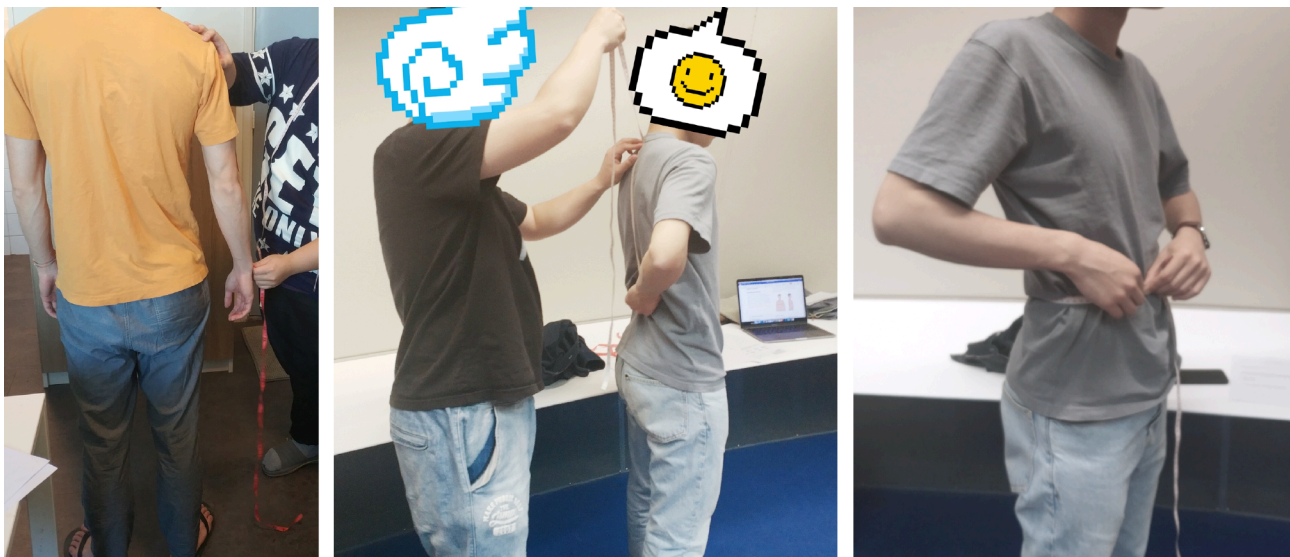
figure 4.9 Participants were taking body measures

Men's body measurements

For all measurements, pull the tape measure so that it sits on the surface of the skin, but doesn't compress the skin. You should be able to put a finger behind the tape, but no more than that. Please try to wear clothes that fit closely or wear nothing at all. If you cannot decide between two numbers, for all measurements longer is better than shorter.

(unit of length: cm)

1	Chest circumference	
2	Neck to chest	
3	Waist circumference	
4	Neck to waist	
5	Shoulder width	
6	Arm length	
7	Biceps circumference	
8	Wrist circumference	

1. Chest circumference

Measure around the fullest part of your chest, in line with your nipples. Keep tape parallel with floor all the way around.
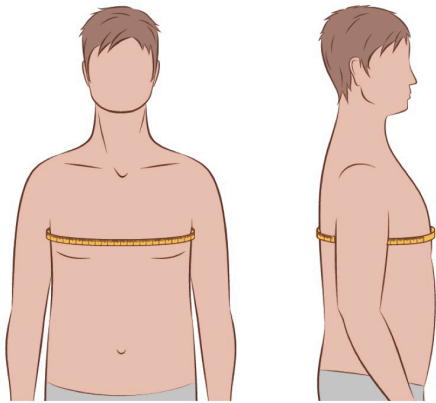
2. Neck to chest

Measure form the back of the neck to the chest line (where you took the chest circumference)
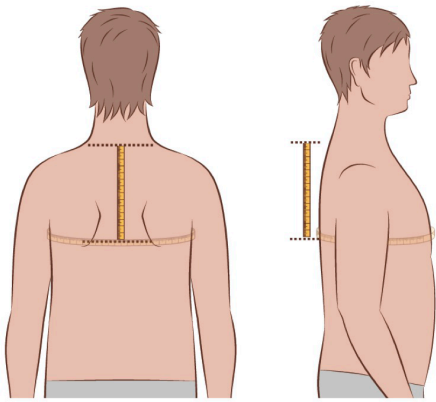
figure 4.10 measuring instruction

3. Waist circumference

Measure around your waist which is located above your belly button and below your rib cage. (If you bend to the side, the crease that forms is your natural waistline.)
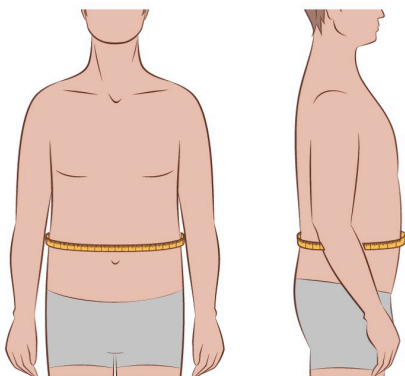
4. Neck to waist

Measure form the back of the neck to the waistline (where you took the waist circumference)
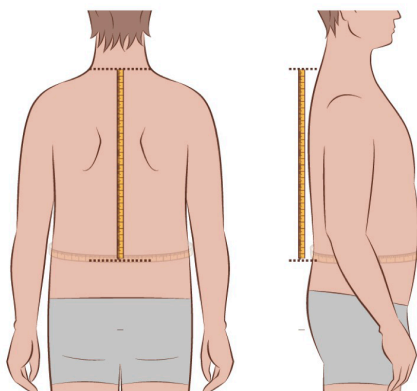
5. Shoulder width

Think of a line going from your armpit straight upwards to your shoulder. Measure between those two points
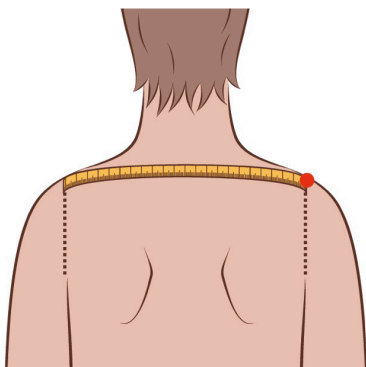
6. Arm length

Measure from the point of your shoulder (where you took the shoulder width measurement), follow your arm down to where you want the sleeve to end
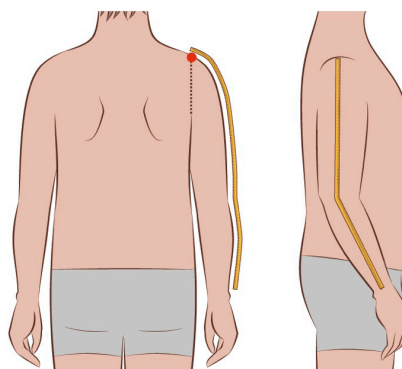
7. Biceps circumference

With your arm hanging at your side and relaxed, measure around your bicep at its fullest point.
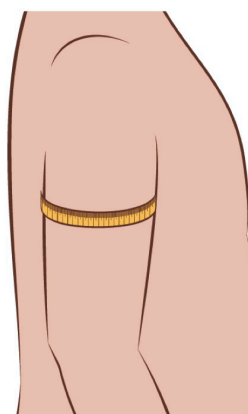
8. Wrist circumference

Measure around your wrist. Hold the tape measure tight to your skin, but do not squeeze your wrist.
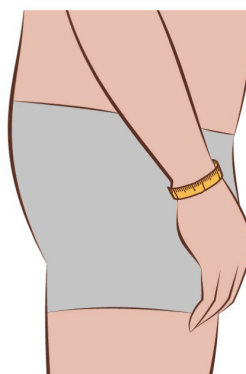
Discussion of results

>Ease of task

Overall, participants thought the task was not hard. However, none of them thought they can finish all the measurements by themselves, especially the length measurements because they needed two hands to hold each end of the tape. The textual instruction was always easy to be missed. For example, although it was mentioned in the beginning that the tap should sit on the surface of the skin and doesn't compress it, participants still had doubts about how tight the tape should be.

In addition, not thinking about the accuracy but only participants' feelings on all the measurements, the length from neck to chest and to waist were thought most hard to measure. It was confusing to measure from where to where.
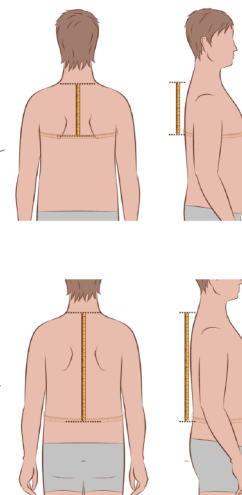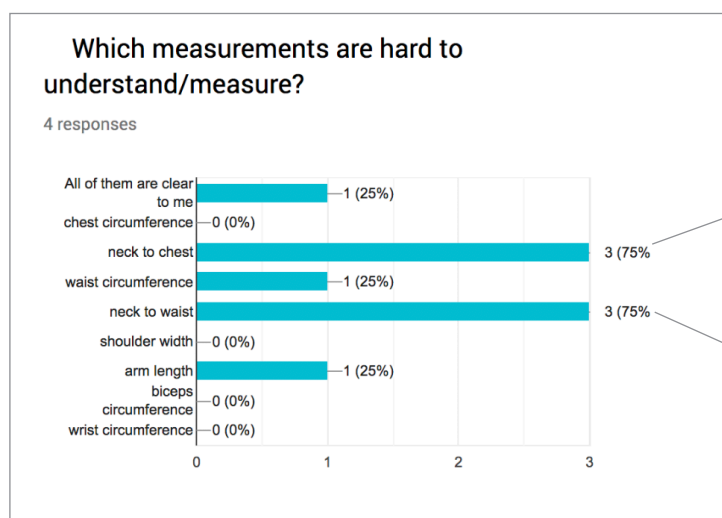
>Accuracy of the result
- Participants did well on most measurements according to the instruction. There were some errors but no big common mistakes. Figure 4.11 shows their self-reported and actual data. The actual measurements were done by me, so minor manual errors might exist.

Some problems I had observed were:
1. Two participants straightened the tape when measuring shoulder width rather than measure up over the curve of the shoulders, which made the result shorter.
2. One participant took the other participant's neck point too low, which made the length from neck to chest and waist a bit shorter.
3. One participant took the other participant's shoulder point too low, which made the arm lengthen shorter.
4. One participant straightened the tape tightly when measuring arm length, which made the result a bit shorter.
5. One participant held the tape at an angle when measuring waist circumference by himself, which made the result a bit bigger.
6. One participant measured his waist lower than waistline, which made the result a bit bigger.

Inputs for design
1. As people bother to read a lot of texts and are easy to miss information, the measuring guide should be made step by step when it is integrated into the website, to avoid overwhelming customers with too much information at a time.

2. To reduce customer confusion, it was decided to skip asking two measurements from customers, which are the length from neck to chest line and the length from neck to waistline. Instead of asking all the measurements from customers, some of them could be predicted with a calculation method developed by the Fieldlab. It is a method that uses age, stature, weight, chest around and waist around as predictors to calculate other body dimensions that are hard to measure on one's own. Whether the prediction can be used as an effective substitute for DIY measurements still needs to be further investigated.

	p1		p2		p3		p4	
	self	checked	self	checked	self	checked	self	checked
Chest circumference	112	111	93	94	98	99	124	124
Neck to chest	25	25	24	24	25	25	21	23
Waist circumference	105	106	78	78	88	85	122	120
Neck to waist	48	48	46	47	52	49	45	47
Shoulder width	43	47	41	43	47	47	49	50
Arm length	63	65	62	63	63	66	61	60
Biceps circumference	38	36	29	30	33	33	41	42
Wrist circumference	19	19	17	17	18	18	20	20

figure 4.11 results of self-reported and checked(by me) body measures

Final Design

The final concept is a product page of well-defined user interfaces, designed for the online process of customizing made-to-measure knitwear. It was built and developed according to the inputs from the design process and the functional requirements stated in Chapter 3. Besides the main concept, there is another introduction page giving information about the company, the ordering process and the product (see figure 4.12). This section explains how the concept works in detail.

figure 4.12 Introduction page

This means we have no garments in stock, only yarns. And these yarns we dye ourselves. We love yarn and love color. Industrial dyed yarn is no match for a hand dyed yarn. The richness of a garment made from a hand dyed yarn is phenomenal.

Usually our yarns are dyed in batches that is big enough for two sweaters. So no two sweaters will look exactly the same. In our studio you'll find lots of undyed wool, and a few dyed yarns and even less garments. Isn't that great? No warehouses full of stuff, we'll only produce that what is needed.

Our future

Currently we are figuring out how to do all of this. What is the best way, for us, to get this working. And what is needed to produce on demand in a way that is cost effective and requires the least resources. Our collection consists of one model, this is because we want to get to now the process in depth. We want to learn everything about this model to get the sizes exactly right, every time. We want to learn more about the model, so we can scale the pattern in a sensible way. Making knit-data is a time consuming process, and knowing the process and results inside and out will help reduce this time considerably.

Home   Product

MEN'S MERINO WOOL KNITWEAR

€209

STEP 1 : CHOOSE A STYLE

crew   v-neck   cowlneck

STEP 2 : CHOOSE COLORS

The garment stitch uses two contrasting colours, of which the main color is also used for the ribbing and the collar.

Steel gray / Turquois

STEP 3 : YOUR SIZE

Create custom sizes   Use standard sizes

With your body measures, we make sizes best fit for you personally. Also try our virtual fitting tool to get the fit right!

+ Add Measurments

ADD TO CART

The model is wearing a sample of *Steel gray / Turquois*

FABRICS

This sweater is made from 100% hand dyed Merino Wool. In our opinion wool is the best material for knitwear. This material breaths and helps you regulate your temperature, so it feels very comfortable. Merino is an Australian breed of sheep, known for their long and soft fleeces. The wool has luster, so it's a bit shiny, and this gives a great depth to the yarns.

This yarn comes in hanks and we dye them using a synthetic dye. The process used for this very elegant. The wool, dyestock and bit of citric acid is used, and then carefully heated to just below the boilinpoint. The dyebath is an exhauting one, so at the end of the proces there is no dye left in the bath. This empty, clear, dyebath is safe to discard in the drain. Wool dyed with this dye is dye is wash and light fast, and meets the oko-tex 100 standard. This means that the dying process is environmental friendly and safe.

WASH AND CARE   ⌄

SHIPPING & RETURNS   ⌄

Different pictures are shown in this area, including pictures of knitwear from different sides and close-ups of knit stitches.

It introduces the material used for the knitwear, how the fabric is made, how it feels and performs, and instructions for wash and care.

A configurator with three steps is used to personalize the knitwear. It provides introductions and relevant information in each step, explaining what every choice means with both texts and images. It allows for readjusting and navigating back and forth among each step.

A special color palette is used to make people understand that the stitch uses two contrasting colors.

The two options of custom sizes and standard sizes are both provided, for customers with different needs and different expected time to spend on shopping.

Part of the tailor-made experience is that you measure yourself. All we need is some basic information and body measurements from you. We will help you step by step on our website.

Your Name:

Height (cm)   Weight (kg)   Age

Measure your body

Chest Around   Shoulder Width
[   ] cm   [   ] cm

Waist Around   Arm Length
[   ] cm   [   ] cm
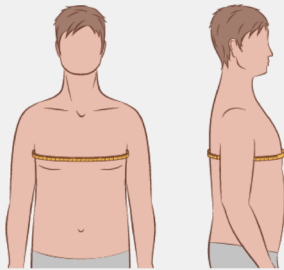
Bicep Around   Wrist Around
[   ] cm   [   ] cm

Done, create garment sizes

Measure around the fullest part of your chest, in line with your nipples. Keep tape parallel with floor all the way around.

Your Name: Jimmy

Height (cm)   Weight (kg)   Age
188   76   44

Measure your body

Chest Around   Shoulder Width
99   cm   [   ] cm

Waist Around   Arm Length
[   ] cm   [   ] cm

Bicep Around   Wrist Around
[   ] cm   [   ] cm

Done, create garment sizes

A guide of taking body measurements is provided as the start of creating custom sizes. It gives step by step instructions supported with illustrations in the left panel when the textbox gets the input focus.

Preferred Fit

tight fit   regular   loose fit

Size Details

We generate custom-fit garment sizes based on your body measurements and preferred fit.

Shoulder width
41cm

Sleeve length
66cm

Sleeve width
20cm

Garment length
65cm

Garment width
52cm

Back to body measures   Save
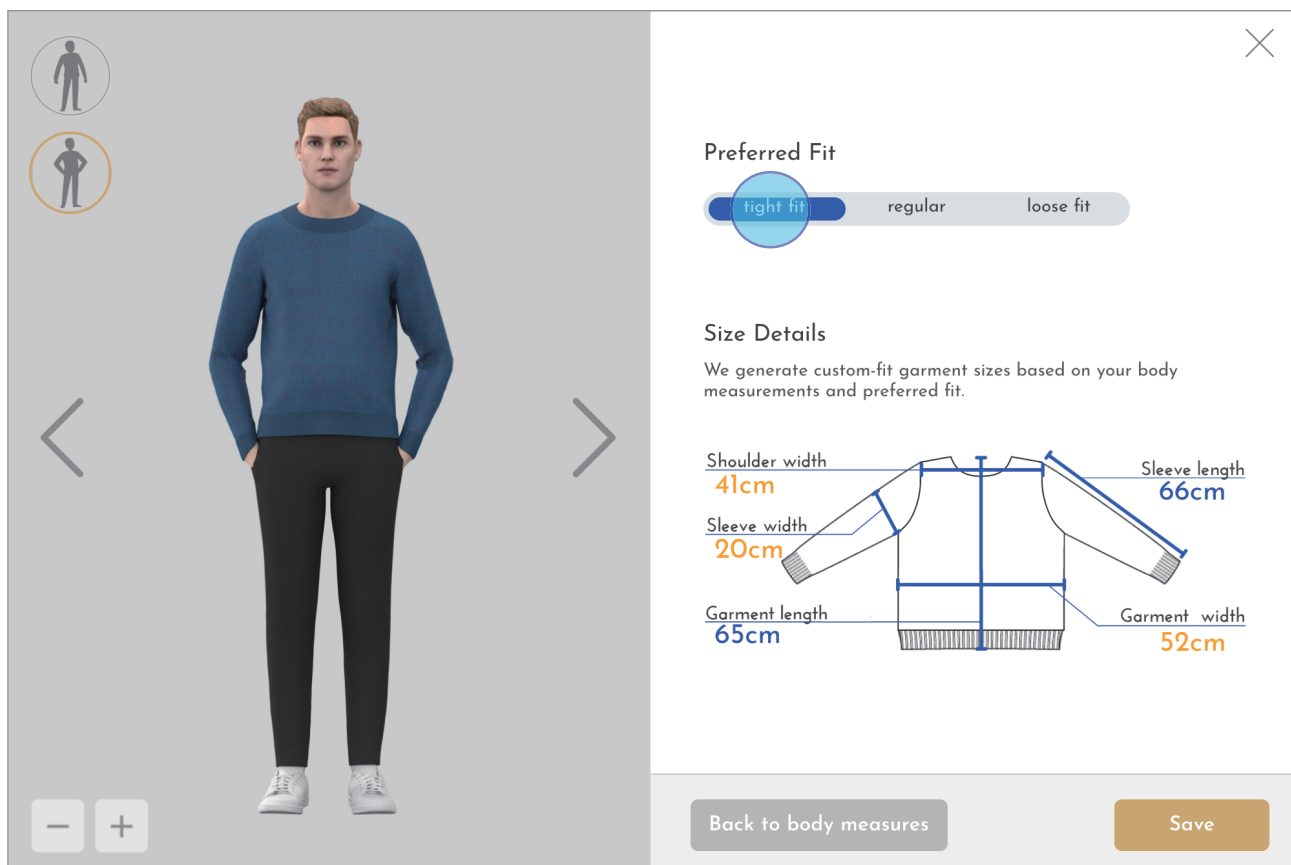
Based on the customer's body measurements, recommended garment sizes are calculated immediately. The function "Preferred Fit" feeds personal tastes into the decision of sizes, giving the customer freedom to choose a tight, regular or loose fit. The "Size Details" part shows the transparent data of the final garment sizes. Its data of shoulder width, sleeve width and garment width will changes based on which preferred fit is chosen.

Preferred Fit

tight fit   regular   loose fit

Size Details

We generate custom-fit garment sizes based on your body measurements and preferred fit.

Shoulder width
43cm

Sleeve length
66cm

Sleeve width
21cm

Garment length
65cm

Garment width
55cm

Back to body measures   Save

Preferred Fit

tight fit   regular   loose fit

Size Details

We generate custom-fit garment sizes based on your body measurements and preferred fit.

Shoulder width
43cm

Sleeve length
66cm

Sleeve width
21cm

Garment length
65cm

Garment width
55cm

Back to body measures   Save

In the virtual fitting room, it creates a digital avatar with the customer's measurements, and shows how the knitwear of his sizes fitted onto the avatar. When choosing different fits, it shows instantly how changes on garment sizes will be actually reflected on body fitting. The knitwear simulates a realistic fabric performance, and is shown in the same neckline and color as the customer's choices.

Preferred Fit

tight fit   regular   loose fit

Size Details

We generate custom-fit garment sizes based on your body measurements and preferred fit.

Shoulder width
41cm

Sleeve length
66cm

Sleeve width
20cm

Garment length
65cm

Garment width
52cm

Back to body measures   Save
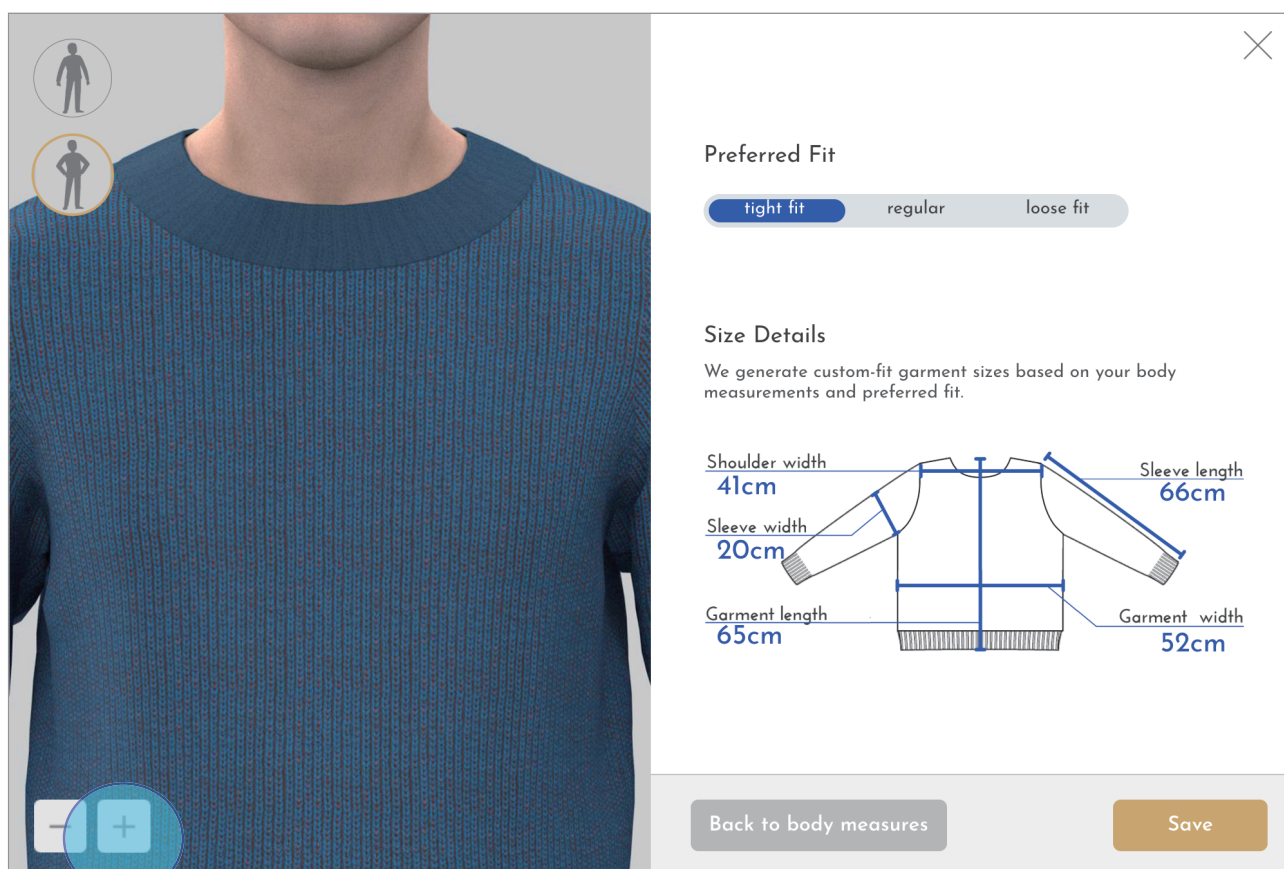
The virtual fitting room includes rich interactivity of rotating the avatar, zooming in and out, and changing the avatar's pose.

Evaluation

User Test

A user test was organized with 13 participants from the targeted group. This section introduces the objective of the study and how it was prepared and conducted.

Test Objectives

The overall objective of the user test was to evaluate how well the final design could meet the design goal and how do people experience the customer journey. Additionally, to find out what are the benefits, limitations and potential improvements based on their feedback.

A list of research questions were formulated with the same structure of the design framework proposed in Chapter 3. After the test, these questions should be well answered.

Layout,look and feel
1. How well does the website reach a good usability?
2. How satisfied are people with the visual style of the website?

Website information
1. How well can people understand the product and the ordering process?
2. How do people think about the company vision?

Configuration process
1. How is the experience of the configuration process? How clear are each step?
2. How is the experience of taking body measurements? How accurate are the self-reported measurements compared with the real and the predicted data?

Virtual fitting
1. How well can the use of virtual fitting provide proxy sensory experience of physically trying on clothes?
2. How do people think and feel about the use of virtual fitting? Does it enhance online shopping confidence and enjoyment?

Product satisfaction
1. How satisfied are people with the result of the personalized garment created online?
2. How satisfied are people with the real garment? Does the virtual fitting make an effective representation of the real garment?

Participants

For the user test thirteen participants with the following characteristics were recruited: 30 – 64 years old, male, Dutch, mid-high socio-economic status, different heights and weights.

Participants were recruited through the network of the company's founders. Some of them knew about the company before but had no knowledge about the content of the user test. They were asked to give fair and honest feedback.

An overview of the participants recruited is shown in figure 5.1. Each of the participants is described through his age, height and weight. Other detailed body measurements of them will be shown in later sections.

Particip ant No.	age	Height (cm)	Weight (kg)
1	32	194	80
2	59	180	78
3	37	183	69
4	37	174	73
5	56	183	68
6	30	183	81
7	60	186	84
8	64	184	71
9	30	186	87
10	63	183	90
11	57	180	77
12	59	182	82
13	57	191	96

figure 5.1 Overview of participants

Prototypes

The tested prototype included all the designed screens of introduction page, product page, some pop-up windows. They were developed into html pages which were fully clickable and interactive. Images of every individualized avatar were prepared and stored in the website in advance as they cannot be created in real time. They were made based on participants' self-measured body data collected via email before the test.

Due to technical limitations, the whole 3D virtual scene wasn't embedded into the product page. So during the step of interacting with the 3D avatar, participants needed to switch to another page to experience all the possible operations.

Settings

The tests were mostly held at the IO faculty. The participants sat in a meeting room and tried the prototype which was set up on a laptop (see figure 5.2). A mobile phone was used to record voice of what they said. I took up the role as facilitator and note taker. For half of the tests, the company also joined the interview part together with me.

figure 5.2 Test settings

Procedure

In order to conduct reliable and consistent user test, a detailed protocol was prepared (see appendix F). The procedure followed it strictly.

01 — Before the session

Invitation & Make appointments

Have participants take their body measurements
Participants were asked to make their body measurements with an instruction before the test. The data were used to calculate recommended garment sizes and make personal virtual fitting images in advance.

02 — Conduct the session

Have user sign a consent form
A consent form was signed by the participant to ensure that they affirm willingly (in writing) to participate in the study.

Start the task
The participant's task was to buy a personalized garment from the website until they check out. They were asked to think aloud as they went through the tasks. During the test, I observed and took notes how they reacted on the given information and what they said and did. Their voices were recorded.

Have user complete a Post-test Questionnaire
After the test was completed, the participant graded subjective measures in a post-test questionnaire.

Semi-structured discussion
After the questionnaire there was a semi-structured interview. Either positive or negative feedback on the design were discussed.

Make body measurements
In the last part of the session, I took the participant's body measurements again. So I had both self-reported measurements and real measurements to compare and check.

Conclude the session
To conclude the session, I thanked the user for participating and let them ask any questions. The company offered them to buy the knitwear for half price.

03 — After the session

Produce the knitwear
After the task, participants had made decisions on each option of the personalized knitwear. Based on that result, the company knitted the garments in their studio.

Evaluation on real garments
After participants received their garments, they gave feedback on their satisfaction on the real garment. The real and virtual fitting effects were compared.

Test Results

In the following section the results of the user test are described. The research questions have been used as a structure to report the results.

Layout, look and feel

1. To what extent does the website reach a good usability?
The System Usability Scale was used to evaluate the ease of use. The participants ranked ten templates questions from 1 to 5, based on their level of agreement. The average final score is 78.08, which had been transferred to a range of 0-100 by subtracting 1 from the score for each odd numbered question, subtracting the score from 5 for each even numbered question, adding up all the new values, and multiplying this by 2.5 (Sauro, 2011). Based on industry standards, a score above 68 would be considered above average, and a score above 80.3 is the top 10% scores. The result didn't reach the top 10% level but very close to it.

The graph shows the average original score for each question to identify which part has usability problems. Question 3 got the most negative feedback, which shows that over half of the participants (P1,2,3,4,5,7,10,13) didn't expect they would visit the website frequently. Question 4&6 also got a few negative scores, which shows that three of them(P1,2,11) needed assistances to use the website and two of them(P2,4) found some inconsistency in the website. The reported problem will be further explained in the following sections.

SUS Scores

Question	Score
1. I thought this website was easy to use.	4.1
2. I found this website unnecessarily complex.	1.6
3. I think that I would like to use this website frequently.	2.7
4. I think that I would need assistance to be able to use this website.	2.1
5. I found the various functions in this website were well integrated.	4.1
6. I thought there was too much inconsistency in this website.	2.0
7. I would imagine that most people would learn to use this website very quickly	4.2
8. I found this website very cumbersome/awkward to use.	1.1
9. I felt very confident using this website.	4.2
10. I needed to learn a lot of things before I could get going with this website.	1.2

Scale: 1 Strongly Disagree — 2 Disagree — 3 Netural — 4 Agree — 5 Strongly Agree

2. How satisfied are people with the visual style of the website?

All the participants were satisfied with the visual style and the layout of the website. The look and feel of the website was thought to be a good fit with the type of the products.

Feedback on visual style (13 responses)

Overall I am satisfied with the visual style and the layout of the website.	7	6

■ Strongly Disagree ■ Disagree ▪ Netural ■ Agree ■ Strongly Agree
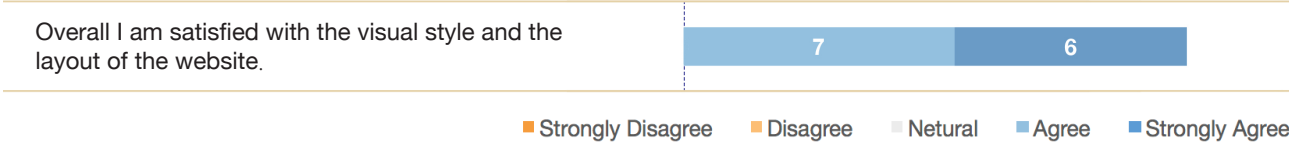
Quotes on visual style	*Main point*
"Looks professional. The design of webpage gives confidence there's a serious company behind." P5	*Visual style looks professional*
"The style itself fits quite well with the with the product. It's not an extremely fashionable thing you buy easily; it's a serious product and the site also shows that." P11	*Visual style fits the type of the product*
"I like the visuals a lot, details like neckline icons are beautiful and well designed." P4	*Details and drawings are well designed*

Website information

1. How well can people understand the products and the ordering process?
All the participants understood the ordering process that they made their choices, entered their sizes, bought the garment, then the garment would be knitted and sent to them. The majority of them thought they got sufficient information to decide a purchase except P6 who would like to know how the price is built up.

Feedback on sufficiency of the information (13 responses)

I can understand clearly the process of buying personalized garments from this company. — 7 | 6

I think I got sufficient information I need to decide a purchase. — 1 | 8 | 4

■ Strongly Disagree ■ Disagree ■ Netural ■ Agree ■ Strongly Agree
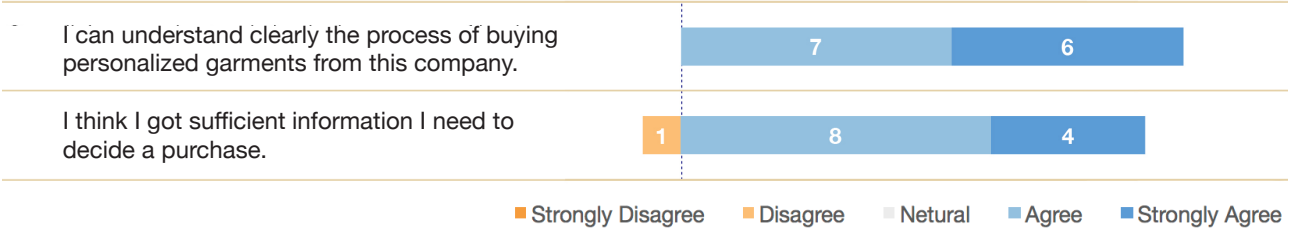
Quotes on needed information	*Main point*
"The company clearly has a vision about reducing waste and being sustainable. Because it shows those ideals about the garment I feel like I want to know why it is so expensive and only simple information like how much a garment usually costs and how much time goes into that would be a decent rationale for me." P6	*Wanted to know how the price is built up*

2. How do people think about the company vision?

The question is answered from three aspects: people's opinions on sustainability claim, customized garments, return policy. First, People's attitude towards the company's sustainability claim could be broadly divided into three different types. The first group of people considered it as a strong claim and a big trigger for them to buy clothes. The second group appreciated it but took it more as a second value. It was a good point for them but wouldn't become a strong reason to buy. The third group didn't think it was they doing something sustainable. Their first concerns were still about how the product satisfies their needs. These questions about sustainability raised people's doubts: what are the fabric's advantages over other materials? where is the garment produced and how is the logistics? Is small-scale production really more sustainable than mass production?

Quotes on sustainable claim	Main point
"The reduction of waste is definitely a trigger for me. Cost-effectiveness and requiring the least resources is something that I'm really interested in." P6	*Sustainability is a strong trigger*
"It's more a second value when buying clothes. Would be a nice thing to tell friends" P4	*Sustainability is a secondary value*
"It wouldn't cross my mind. It's not that I consider me doing something sustainable it's more for my own wishes." P12	*Sustainability doesn't add value in this case at all*

Secondly, people's attitude towards customized garments were all quite positive, especially for those who have some problem finding the perfect sizes. Some people mentioned that it's a common case when their size or color in shop are sold out, which is disappointing. Some people mentioned when they buy standard sizes, the fit on different body parts sometimes cannot be satisfied at the same time. For example when the garment length is perfect, the sleeves would be too long. Some people don't enjoy shopping and trying things on in shops. For these people, customized garments could be of great value. Additionally some people mentioned the personalized garment and something handmade makes it more unique in some way.

Quotes on customized garment	Main point
"This is a good advantage. It saves the effort of choosing size. You are sure it's made with your sizes." P8	*Customized size saves effort of choosing sizes*
"It's important that the size is really good." P7	*Good size is important*

Thirdly, regarding the return policy that the product is not possible to be returned, the common attitude was that it's logical, understandable and acceptable. However, it did make the risk of taking a try higher and increased customers' uncertainty. Given the lack of opportunity to physically examine the product and the lack of in-person support, it seemed very crucial to build confidence and to convince customers for the first time. As long as people make a successful purchase for one time, they will gain trust in their size profiles and the company's design, then things will get very easy for a returned customer.

Quotes on return policy)	Main point
"For this product which is quite expensive in a way, I doubt if I would do it by Internet. I have the feeling for a thing like this, you have to be really sure. You would like to fit it first to try and how it looks like. Because you can't send it back, that I think for me it would be a big threshold to pass." P11	*Insecure to buy clothes from a new brand on Internet*
"I can totally understand (the product cannot be returned) if it's designed to be completely fitted to me. The thing is that you have to put in a lot of efforts to get it right and you have to get it right the first time, if not then it's too easy for me to fall back on what I always do" P6	*Had pressure to get everything right the first time*
"Once you prove it for the first time, you can do it online easily for next years." P2	*It would be easy to repeat the purchase process in the long term*

Configuration process

1. To what extent are people clear about all the options in the ?
The experience on the complete configuration process was thought good. Participants showed great willingness to spend some time and effort on this process to create their personalized garments. But if we take a closer look at each step of it, there are still some confusion on different choices, especially on choosing colors.

Feedback on configuration process (13 responses)

Statement					
Overall, I am willing to spend some time and effort to personalize my garment by going through these steps.		1	2	10	
The options of **neckline style** are clear to me. I can make a choice based on given information.			1	12	
The options of **colors** are clear to me. I can make a choice based on given information.	1	1	6	3	2
The two ways to **decide garment sizes** are clear to me. I can make a choice based on given information.	2	1		6	4

■ Strongly Disagree   ■ Disagree   ■ Netural   ■ Agree   ■ Strongly Agree

The first step of choosing neckline was clear and simple for everyone. All the participants thought they were able to make a choice on their liked style. Real photos could tell clearly how each style looks like, and the illustrations on configuration panel have a good match with the pictures.

The second step of choosing colors was a hard decision to make for most participants. Only five of them (thirteen in total) agreed that they got enough information to choose a color. The problem reported were in two aspects: the way of presenting colors, the worry of color differences on screen. Over half of the participants(P2,4,5,6,8,9,11,12) mentioned that how every color looks on the garment from a certain distance was missing, which was a necessary clue for making decisions. Three participants(P2,4,10) mentioned small color icons didn't match with fabric pictures completely. That's also why P2,4 thought the website had some inconsistency when they scored Question6 of SUS. Another concern of choosing color is the differences between the colors shown on screen and in reality. Considering it's not a small purchase and you can not return for color issues, this worry could hold some participants back. Nearly half of them (P2,4,5,6,8,11) would prefer to check the fabric in real life if possible. However, there were also participants who didn't really worry about color issues that much, they went straight confidently and were able to make choices without hesitation(P3,7).

The third step of choosing one way to decide garment sizes was clear to the majority except for two participants. P7 didn't notice the option of standard sizes until seeing the question in the questionnaire. P12 was a bit confused about where he was in the process in decision-making at that moment. So they disagreed with the statement.

Regarding the preferred way to choose sizes, ten of the thirteen participants preferred to create custom sizes in this case. P6 was not sure because it depends on if he is doing an impulsive buying. P10 was also not sure, he would like to decide after comparing where are the differences between the size results of the two ways. P2 preferred to use standard size partly because he doesn't have real size problems with clothing.

Quotes on the way of presenting colors	Main point
"The way to present colors gives details, but how it looks on the whole sweater is tricky to see." P4	*Tricky to see how each color looks on the whole garment*
"I will appreciate to see how every color looks from distance. At this moment it's hard to make decision. If you look this picture (pointed at the photo in which model wears a cowlneck knitwear of Turquois / Scarlet), in this distance it looks like only one color, red is not visible." P8	*Noticed color difference in photographs between close-up and normal viewing distances*
"I would expect that every step you take and choice you make would be visualized (…)Small pictures don't match with fabric pictures completely. They give a hard feeling but the photos give a soft feeling." P2	*Expected visualization of every steps; Noticed color mismatch between small icons and photographs*
"I made a choice based on the photos and not so much on the these icons so as I said that there is too big a difference between those two."P10	*Noticed color mismatch between small icons and photographs*

Quotes on the worry of color	Main point
"The thing that holds me back a little bit is the color that I wouldn't really know how a color that I picked on the website would look in real life." P6	*Uncertain about the color shown on screen*
"I preferably see it in live before purchase." P5	*Preferred to check colors in live*
"I have no worries about the color at all." P7	*No worries about colors at all*

Quotes on size choices	Main point
"However if I was doing an impulsive buying of this sweater then I would probably just go for the the standard sizes." P6	*Impulsive buying will influence the decision*
"I can imagine that once I have ordered some products from the brand and I feel how their clothes fit then it's easier to to perhaps adapt some sizes, so then the custom size should be preferred." P10	*Preferred to adapt some custom sizes after a first try*

3. How is the experience of taking body measurements? How accurate are the self-reported measurements and the predicted data compared with the real and?

According to user feedback, the step of taking body measurements itself is not a difficult task, but the problem is the feeling of uncertainty and insecurity arisen in the process. People know that the customized size would be largely determined by the result of their body measurements. So they want to be very sure about it when they finally confirm the data with the system. Some of them would like to see more detailed guides of how to do it right and what needs special attention. Additionally, it happened to three participants that they didn't find a decent soft tape at home, but managed to do it by using a sting+ruler or a metal tape in the end. This practical problem in real life could make the result very wrong or could deter customers from continuing the ordering process.

Quotes on taking body measurements	Main point
"Now it's like a very small step(in the test), but actually a crucial step in real situation. I would like to have more detailed step by step instructions or video tutorials. Would like to have some warnings about what's right and what's wrong, then I will have more confident that I do it right." P5	Wanted to have more detailed guide and warnings on possible errors
"If I really want to make sure that it totally fits me then I would definitely take the time to take my measurements and make sure I got it 100% right. " P6	Needed to be very sure about every measurement before really buying it
"I don't have a tape measure at this moment. It's a bit strange because I always get one. Indeed it's a bit difficult to do it yourself. And I start doubting if it's correct what I did." P13	Didn't find his tape; Hard to take self measurements alone
"It was a bit tricky to measure my arm myself. Instead I measured a sweater's sleeve to estimate my arm length" P3	Tricky to measure arm length oneself

To know how well customers are able to take body measurements right, their self-reported measurements is compared with the real measurements. The self-reported measurements were gathered through email before the test. The real measurements were taken by me at the end of the test session. The results are presented in two groups: participants who measured themselves on their own; participants who asked someone else to measure them. It seemed that people with other's help still made mistakes, but were less likely to make big mistakes. Looking at the data (see the table below), shoulder width was the most problematic dimension, and arm length was not good either. Chest and waist around were relatively much more accurate. Wrist around was done almost perfect.

Body measurements of participants who took it on their own

	P2		P3		P5		P9		P11		P13		Errors
	self	checked	self	checked	self	checked	self	checked	self	checked	self	checked	>3%
Chest around	100	102	101	99	91	93	97.5	100	94	98	112	114	>5%
Waist around	102	96	85	83	84	82	88	88	91.5	91	108	108	>7%
Shoulder width	42	42	41	41	38	43	35	46	30	42.5	42	48	>20%
Arm length	60	63	63	63	63	64	64	64	60	61	61	67	
Bicep around	32	32	26	30	28	28	35	35	30	32	33	34	
Wrist around	18	18	17	17.5	18	17	18.5	18	17	17	18	18	

Body measurements of participants who had it measured by someone else

	P4		P6		P7		P8		P10		P12	
	self	checked	self	checked	self	checked	self	checked	self	checked	self	checked
Chest around	95	96	98	101	100	101	92	94	101	104	107	106
Waist around	84	85	86	85	95	94	80	82	106	105	97	97
Shoulder width	37	40	45	47	43	47	39	45	41	43.5	45	46
Arm length	64	61	64	65	66	65	67	65	63.5	66	64	65
Bicep around	30	32	33	33	33	35	28	28	32	33	30	32
Wrist around	16	16	19	18	18	18	18	18	18.5	18	18	18

To have a further investigation on how well the measurement prediction works, the predicted data is calculated to compare with the real body measurements. The calculating method is based on an outcome from Fieldlab, which uses age, stature, weight, chest around and waist around as predictors to calculate other body dimensions. As shown in the table below, the predicted arm length is calculated. Compared with their real arm length, the average absolute deviation of predicted results is 1.31%, and that of the self-report results is 2.48%, which means the predicted arm length is actually more reliable than participants' self-report data in this case.

Comparison of predicted, self-reported and real arm length

	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11	p12	p13
Age(year)	32	59	37	37	56	30	60	64	30	63	57	59	57
Weight(kg)	80	78	69	73	68	81	84	71	87	90	77	82	96
Height(cm)	194	180	183	174	183	183	186	184	186	183	180	182	191
Chest around(cm)	98	102	99	96	93	101	101	94	100	104	98	106	114
Waist around(cm)	87	96	83	85	82	85	94	82	88	105	91	97	108
Real arm length	67	63	63	61	64	65	65	65	64	66	61	65	67
Self-report arm length	67	60	63	64	63	64	66	67	64	63.5	60	64	61
Deviation from the real arm length	0.00%	-4.76%	0.00%	4.92%	-1.56%	-1.54%	1.54%	3.08%	0.00%	-3.79%	-1.64%	-1.54%	-8.96%
Predicted arm length	68.42	64.11	64.81	61.11	64.59	64.41	65.97	64.99	65.27	65.14	63.70	65.00	68.61
Deviation from the real arm length	2.12%	1.76%	2.88%	0.18%	0.93%	-0.91%	1.49%	-0.01%	1.99%	-1.30%	4.43%	0.00%	2.41%

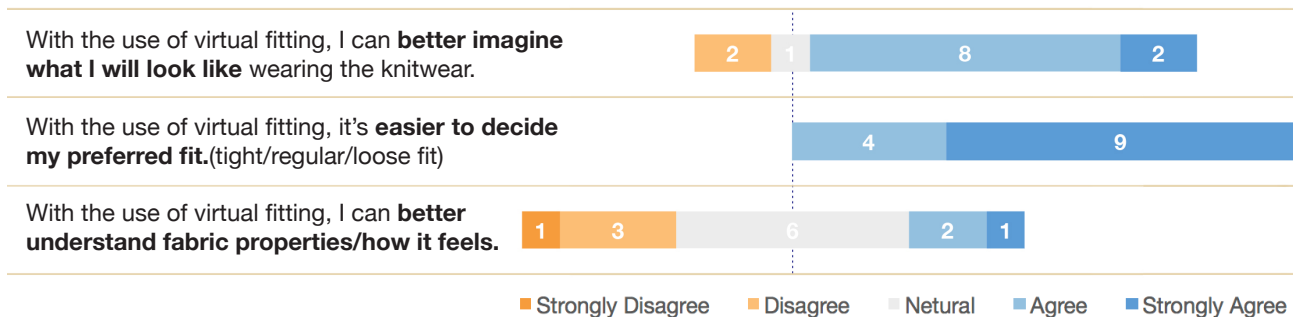| Average Absolute deviation of self-report armlength	Average Absolute deviation of predicted armlength
2.48%	1.31%

Virtual fitting

1. How well can the use of virtual fitting provide proxy sensory experience of physically trying on clothes?

The perceived usefulness of virtual fitting in providing sensory experience is evaluated from three aspects: how people look like when wearing the knitwear; how the tight/regular/loose fit suits them; how the material/fabric feels. It's worth noting that this function behaves very differently in different aspects. The use of it seemed to have a stronger effect in simulating visual experience of trying on clothes, but lower effect in giving tactile information.

First, most participants (ten out of thirteen) thought it helps to imagine what they will look like with the knitwear. They were able to connect the avatar to themselves. Secondly, all of them thought it helps to decide their preferred fit (tight/regular/loose fit), and the level of agreement on this is very strong. It shows in a good way how different fit choices will actually be reflected on body fitting. Thirdly, only three of the thirteen participants thought they understand fabric properties better from the use of virtual fitting. They didn't learn much extra information of material properties.

Feedback on the usefulness of virtual fitting (13 responses)

With the use of virtual fitting, I can **better imagine what I will look like** wearing the knitwear. — 2 | 1 | 8 | 2

With the use of virtual fitting, it's **easier to decide my preferred fit.** (tight/regular/loose fit) — 4 | 9

With the use of virtual fitting, I can **better understand fabric properties/how it feels.** — 1 | 3 | 6 | 2 | 1

■ Strongly Disagree ■ Disagree ■ Netural ■ Agree ■ Strongly Agree

2. How do people experience the use of virtual fitting? Does it enhance online shopping confidence and enjoyment?

For the majority of the participants, the use of virtual fitting is a good point of the website. Ten of the thirteen participants thought that it boosts their confidence in evaluating clothing fit online; Nine participants thought that it enhances shopping enjoyment and engagement. Eleven participants thought that overall it is a value-added function. However, also some of them had the opposite opinion. The negative comments mainly come from the distrust in the technology and dislike on the avatar, as shown in the quotes on experience of virtual fitting.

Regarding the feeling of seeing a 3D virtual avatar representing oneself, it didn't cause dissatisfaction with real bodies, although the former research shows this could happen. But contrary to this worry, one thought the avatar has a better body than his actual body. This is an interesting finding that apart from the possibility of being frustrated by seeing one's virtual body, people could also feel being flattered by the virtual body.

Feedback on the experience of virtual fitting (13 responses)

The use of virtual fitting **boosts my confidence** in evaluating fit of clothing online. — 2 | 1 | 7 | 3

The use of virtual fitting **enhances my shopping enjoyment and engagement**. — 3 | 1 | 5 | 4

Overall, I think virtual fitting in web store is a **value-added function**. I would like to use it. — 1 | 1 | 5 | 6

■ Strongly Disagree ■ Disagree ■ Netural ■ Agree ■ Strongly Agree
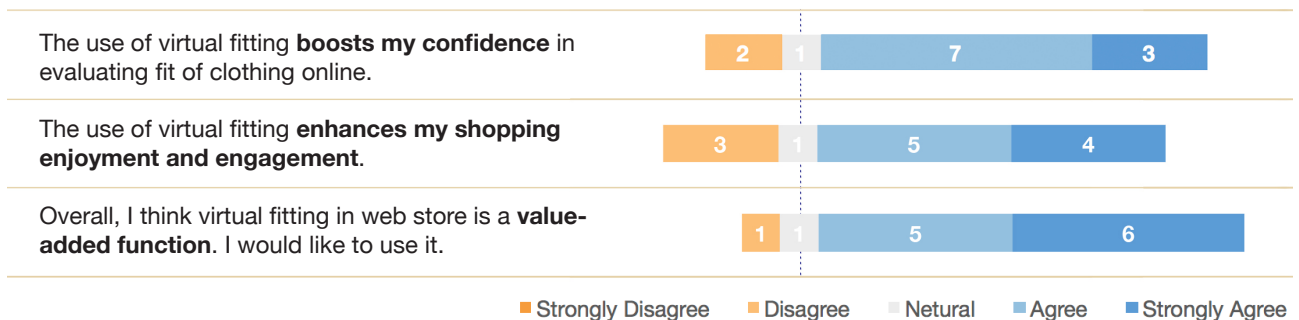
Quotes on virtual fitting (the look)	Main point
"This is nice. You made a choice, then you can see how other people see you." P8	Able to connect the avatar to himself
"I can kind of recognize my body here. I knew it would be my body shape as I am quite big." P13	Able to connect the avatar to himself
"I can imagine myself there" P9	Able to connect the avatar to himself
"Definitely works for the first impression. Of course not a complete match, obviously he has a different head" P3	Able to connect the avatar to himself
"I didn't recognize it's my body at first. I just thought it was a demonstration of tight and loose fit."	Didn't recognize the avatar represents his body at first
"It's useful but hard to really trust in it, it still looks like a computer object. His neck looks too thick." P1	Hard to truly believe in it

Quotes on virtual fitting (preferred fit)	Main point
"Loose fit looks realistic that you really can see it's very floppy because it's too big." P9	Virtual fitting shows a realistic effect of different fit
"The preferred fit it does shows you in a good way what is seen as tight or regular that actually really helped in having getting me to select the right fit." P6	Virtual fitting is helpful for deciding preferred fit
"Virtual images give you a good idea of what different fit means. It makes more sense to answer this when seeing it on an avatar." P4	Virtual fitting is helpful for deciding preferred fit

Quotes on virtual fitting (material perception)	Main point
"My impression on the material is still mostly based on experience with knitted fabric. I don't learn extra things such as how stretchy it is from it." P1	Didn't learn extra material information from virtual fitting
"If there was something of a pointing text above it that said zoom in to to see the detail of the fabric then I would understand material fabric properties better if I was directed to." P6	Didn't learn extra material information from virtual fitting (unless the system guides him to that)
" I can get it a bit, from the way how the clothing folds" P10	How the clothing folds in virtual fitting gives some material information
"Zooming in very much helps learn some fabric properties. If looking from far, a bit tricky to see" P3	Close-up view is more helpful to learn material information
"I am very impressed by the effect that you can see the stitches so clearly" P5	Stitch details in virtual fitting are amazing

Quotes on experience of virtual fitting	Main point
"It well connects the advanced technology and the attribute of personalization." P5	The technology is well adapted to this case
"I think it's a good point for the website when you have it. It is nice to to turn around and look how to have the fitting is." P10	Virtual fitting is of added value and interesting
"Virtual fitting gives some kind of feedback your data got somewhere, then you start to have more trust in the system." P1	Virtual fitting enhances trust on the system
"I'm a bit skeptical about the technology actually working and actually making a good representation of of me and my body mass measurements. "P5	Skeptical about the technology
"I'm flattered with my avatar, I think there's this part [pointed at the belly of the avatar] is a bit underestimated…" P12	Felt flattered by the avatar
"It didn't give me fun, it is very functional. But if you want to create traffic on the site, it has to be fun." P12	Very functional, but not fun
"The avatar was very awkward to look at. The arms so strange a bit a part from the body. " P2	Avatar looks weired

Product satisfaction

1. How satisfied are people with the result of the personalized garment created online?

Feedback on product satisfaction (13 responses)

| The garment I created meets my needs very well | 2 | 8 | 3 |

■ Strongly Disagree ■ Disagree ■ Netural ■ Agree ■ Strongly Agree
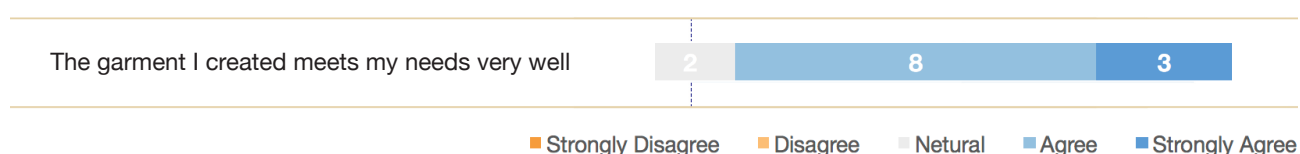
Almost all the participants were satisfied with the garment and expected good quality of it. Figure 5.3 shows the fitting effect of what every participant decided to order in the end. It can be seen from the overview that the differences of everyone's final fitting effects are distinguishable.

To decide on the final garment sizes, four participants (P1,4,7,10) wanted to further modify some sizes based on recommended sizes even though the website didn't provide that possibility. P7 wanted to make the garment longer because he thought it looks too short on the virtual model. P10 wanted to make the garment longer because he thought in the photograph that the garment looks rather short on the model. P1,4 modified some sizes because they wanted to more or less copy the size of their own perfectly-fit sweaters. Inversely, some participants were less aware of the sizes and said they wouldn't bother checking the garment sizes with another garment or they wouldn't have thought of it if there is no reminder.

2. How satisfied are people with the real garment? Does the virtual fitting make an effective representation of the real garment?
Due to time limitations, this part of the test was done with the first two customers who received their knitwear. Both of them thought the garment fits perfectly, and confirmed the usefulness of virtual fitting that it makes an effective representation of the physical try-on. A comparison of the screenshots of virtual fitting and the photographs of physical try-on was done (see figure 5.4&5.5).

P1, 194cm
Modified regular fit
(longer garment and sleeves)

P2, 180cm
Tight fit

P3, 183cm
Regular fit

P4, 174cm
Modified tight fit
(longer and tighter garment, tighter sleeves)

P5, 183cm
Tight fit

P6, 183cm
Tight fit

P7, 186cm
Modified regular fit
(longer garment)

P8, 184cm
Tight fit

P9, 186cm
Regular fit

P10, 183cm
Modified regular fit
(longer garment)

P11, 180cm
Tight fit
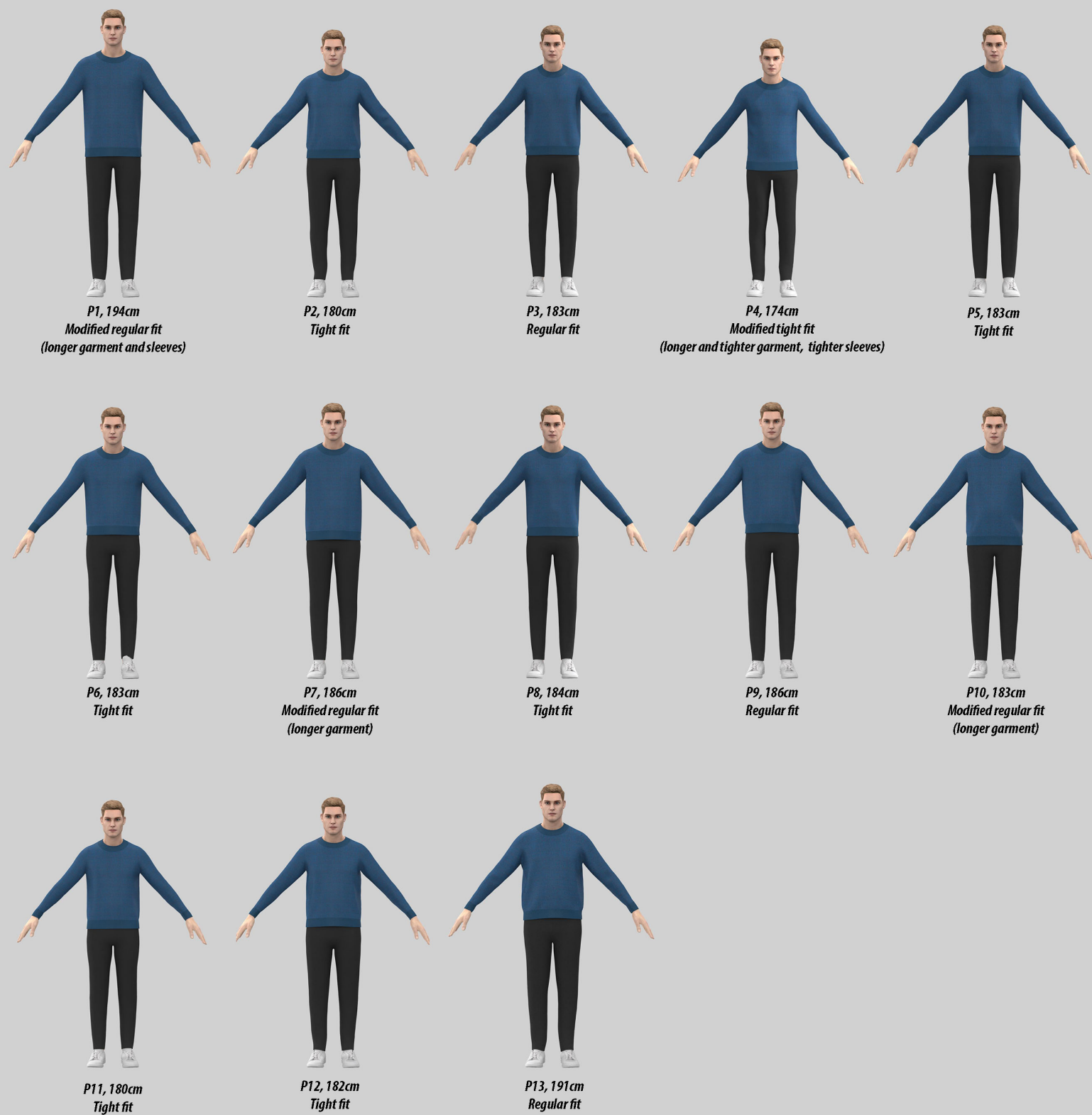
P12, 182cm
Tight fit

P13, 191cm
Regular fit

figure 5.3 Overview of the final fitting effect of every participant

figure 5.4 comparison between virtual fitting and physical try-on

Customer comments

The first customer thinks the real knitwear fits him perfectly. The virtual fitting is a good representation except that the avatar's neck is thicker than the head, which he thinks is an opposite body feature of him. And he mentioned that in real life he can stretch or pull up the bottom ribbing to freely control the garment length, but in virtual fitting he can only see still images of how it drapes straight down. The experience of fine-tuning the garment is missing with the virtual fitting.

Dissimilarities found in the comparison

> Body
- The avatar has a thicker neck
- The avatar has more sloped shoulders
- The avatar looks thinner from a side view

> Garment
- The real garment has more folds
- The real garment has a tighter neck
- The real garment gathers close around his waist

figure 5.5 comparison between virtual fitting and physical try-on

Customer comments

The second customer is satisfied with how the knitwear fits now, but he thinks it needs more time to wear it for a while until he can make a final conclusion on its fit. He thought the virtual fitting is a good representation of real fitting that he can rely on.

Dissimilarities found in the comparison

> Avatar
- The avatar has a straight back while the person's neck leans forward a bit
- The avatar has more sloped shoulders

> Garment
- The real garment has more folds
- The real garment is more close to the skin

Conclusions

This section makes a conclusion of the final concept and reflects on the evaluation results based on the design requirements proposed before. The review also leads to the recommendations for the future design.

Concept Review

The initial objective of the project was to develop an online solution that enables people to personalize, virtual fit and order made-to-measure knitwear, so as to achieve customer satisfaction on fit. After the research stage, the explicit and specific goal to guide the design was established, "To design a website that enables customers to customize and order knitwear made to their measurements, in all possible looks, sizes and fits. Include the use of 3D virtual fitting in the website to boost customer confidence in evaluating clothing fit online and shopping enjoyment. In the end deliver with the real garment that achieves customer satisfaction".

The concept development phase had resulted in the design of well-defined user interfaces heading towards the design goal. A final website concept was built to achieve the customer experience described in the design statement. From testing the website prototype with thirteen participants, it was observed that the concept is able to support people to finish the online process of customizing made-to-measure knitwear. All the participants managed to get a result of the personalized knitwear in different looks, sizes and fits, and the majority were satisfied with both the result and the experience of configuring it. But meanwhile the test also reflects some problems in certain parts of the customer journey. One big concern is the difficulty to choose color due to the lack of pictures and worries on color differences. Another concern is the errors with body measurements. The accuracy of self-reported data is hard to guarantee, and people are easy to feel insecure and uncertain whether they do it right.

With regards to the experience of using 3D virtual fitting, it achieves its intended effects for the majority participants. The test result shows that most of them gain higher confidence in evaluating fit of clothing in online environment, as well as higher shopping enjoyment. However, there are also a few negative comments should be noticeable, which mainly come from the distrust in the technology and the dislike on the avatar.

With regards to the perceived usefulness of 3D virtual fitting, it has a strong effect in giving visual information of how it looks to try on the garment with different sizes and fits, but very limited effect in giving tactile information of how the fabric feels. This conclusion is consistent with the findings of "Activity II. Deciding the garment sizes" in the design process. So it's learned that the virtual try-on experience is able to compensate for the lack of sensory inputs in online environment, but still not enough to be a complete substitute for physical try-on.

Discussion based on design requirements

The design requirements proposed in Chapter 3 are used as a criteria to assess the final concept (see figure 5.6), to check what has and what hasn't been achieved.

The general requirements of reaching good usability and appropriate visual style are met well.

Since there is a long list of the functional requirements, only those that are not implemented well are discussed here. Part of Requirement 2.1 of providing fit tips on the specific garment is not implemented, this information about the garment is unknown yet as it's still in the testing stage. Requirement 2.5 of providing an effective guide of taking body measurements is not met well, as the accuracy of self-reported data is not ideal enough. Requirement 2.8 of creating a digital avatar needs to be improved, as there still exist some dissimilarities between the real body and the avatar. Requirement 2.9 of simulating realistic material properties and knitted texture needs to be improved, for that the fabric performance and the color of the virtual garment are still not an accurate match with those of the real garment.

Regarding the experiential requirements, Requirement 3.1 of enabling people to make choices confidently is overall met well, except that the step of choosing colors causes some hesitation. Requirement 3.2&3.3 of boosting customer confidence in evaluating fit of clothing and shopping enjoyment are achieved for the majority people (ten out of thirteen). Requirement 3.4 (customers' needs are satisfied with the result of their personalized knitwear created online) is overall met well, but some people asked for modifications on garment or sleeve length during the test, which was granted but was not a function available on the website. Requirement 4.4 (Customers who place an order are satisfied with the actual knitwear they receive in real life) is hard to say whether it's achieved due to the limited amount of feedback. For the two people who received their real knitwear, both of them are satisfied with its look and fit, and think virtual fitting is an effective representation of the real fitting effect.

General requirements	
1.1	The website should reach good usability.
1.2	The website should have an appropriate visual style.
Functional requirements	
2.1	The website should tell what material is used for the knitwear, how it feels and performs, instructions for wash and care. Also provide fit-related information and fit tips on the specific garment.
2.2	The website should show both close-ups of knit stitches and the pictures of knitwear from different sides.
2.3	The configuration process should provide relevant knowledge/expertise for decision-making in each step.
2.4	The configuration process should allow for readjusting and navigating back and forth among its each step.
2.5	The website should provide an effective guide of taking body measurements to get accurate data from customers.
2.6	The website should provide transparent data of the recommended garment dimensions that are calculated from personal body measurements.
2.7	The website should feed personal fit preference into the decision of sizes.
2.8	The virtual fitting room should use a digital avatar representing individual customer and show how the knitwear fitted onto the avatar.
2.9	The virtual garment should simulate realistic material properties and knitted texture.
2.10	The virtual fitting room should show how every change on garment sizes is actually reflected on body fitting.
2.11	The virtual fitting room should include rich interactivity with the 3D scene.
Experiential requirements	
3.1	Customers are willing to go through the configuration process, able to make choices confidently, without burden of choice or preference uncertainty.
3.2	Customers have higher confidence in evaluating fit of clothing online from using virtual fitting.
3.3	Customers have higher shopping enjoyment and engagement from using virtual fitting.
3.4	Customers' needs are satisfied with the result of their personalized knitwear created online.
3.5	Customers who place an order are satisfied with the actual knitwear they receive in real life

figure 5.6 Design Requirements

Limitations

This section discusses some limitations of the design and the project, and analyses what possible implication might be caused.

Property parameters of virtual fabric
In CLO3D, virtual fabric is expressed as it is made in real life, combining material + texture. Its physical property is emulated by applying all detailed property values, such as stretching, bending, buckling, density and others. Many of these need to be accurately measured by using specific equipment. However, in this project these values are just estimated by constantly adjusting the property values until the virtual fabric performs the same way as the real fabric (see Page 29). So as a result, the simulation of the virtual knitwear is not able to be expressed 100% accurate. There is room for optimization to make the simulation more realistic and closer to how it looks in real life.

Incomplete customer journey
The project mainly focuses on the experience of online configuring and virtual trying on the knitwear, which is part of the entire online purchase process. But other factors outside the design scope could also have big influences on the overall customer experience, such as payment methods, delivery service and others. During the final user test, the step of taking body measurements was done in advance, and the payment/shipping part was left out. The incomplete customer journey may also be a limitation to understand how people will actually react in real situations.

Limited functioning prototype
The website was developed into a prototype which is fully clickable ad interactive, but due to technical limitations, the virtual fitting part was functioning limitedly. First, the virtual knitwear show the same neckline and the color no matter what the participant actually selected, because there are too many choices combinations to visualize in real time. Second, the 3D scene wasn't embedded into the product page, so the participant experienced its full function on a separate page. These limitations might reduce the playfulness of the function and cause experience inconsistencies, therefore adversely affected the participant's actual feelings on the use of virtual fitting.

Product satisfaction
The real garments were produced based on the right body measurements checked by me, not the self-reported data from the participants, which will not happen in real situations. So one limitation is that the satisfaction on real garments could be reduced if people took their measurements incorrectly.

Recommendations

Based on the conclusion and some suggestions from participants, recommendations and further necessary steps are discussed in this section.

Virtual fitting
- Add interesting features
Some people mentioned they expect to see more interesting features of virtual fitting. For example it can be designed more like a dressing room, so people can match the knitwear with different pants, shoes, with or without a shirt inside. How to develop the fun part of this function would be a relevant topic to improve the customer experience.

-More realistic simulation of the fabric
As mentioned in the limitations, there are some fabric properties can only be measured with special tools. If more precise value can be applied to the virtual fabric, the simulation of it will definitely be more close to reality.

- More precise avatar
As shown in the comparison of the real and virtual fitting effects , there exist some dissimilarities between the real body and the avatar. More measurements can be predicted and applied to the avatar to build a more precise representation of individuals, even though these measurements may not be needed to make garments.

Extended service
For many people it's still a big limitation of online shopping that they cannot see the color and feel the fabric in real life. It's especially relevant in this case because the touch of knitwear is an important quality. And its colour palette is quite special that every stitch is composed of two colors, every single color of the hand-dyed yarn is variegated, and the two colors look like mixed from normal viewing distance. Therefore some suggestions are put forward to solve this limitation.

-Provide the service of sending fabric samples. Customers can order some small fabric swatches to have a check, so they can make the final decision more confidently.

-Set up an offline store to display the materials and garments, as well as to advertise the brand. Customers can go and visit to learn more about the product.

-Organize some activities like company tours or workshops. Customers who have interests can not only learn more about the product, but also know the story behind on-demand fashion better.

Taking Body Measurements

There are two main problems about taking body measurements: the inaccuracy of self-reported results and customers' feelings of uncertainty arisen during the process. It's necessary to find a better way to get body measurements from customers, in order to improve both the reliability of the data and customers' confidence. Some directions for improvements are proposed.

-Make use of measurements prediction

There are many opportunities to make use of the prediction method developed by the Fieldlab. By predicting some measurements, what are hard to measure can be skipped to ask from customers. It can also be used to check if the customers enter the data within a normal range, to give some warnings if obvious errors are detected.

-Introduce other technologies

Some technologies such as 3D scan or mobile scan can alternative the way of measuring with a tape. The future research can focus on how to use and adapt these technologies to certain contexts well.
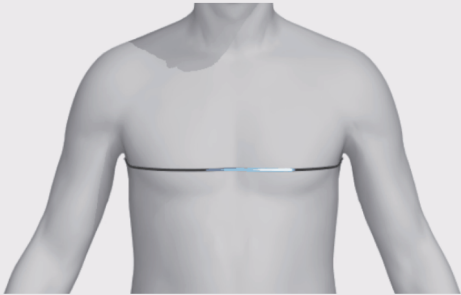
-Improve the guide

The guide should give more details on measuring from where to where, what is right and what is wrong. Figure 5.7 shows an improvement of the interface of the instruction by using 3D animation to explain how to take the measurement and adding tips that need attention.

Modifying garment sizes

Some people wanted to modify their garments sizes, especially for the garment length. Making the garment sizes fully editable would increase the process complexity and add much extra work to the company, but limiting the function might also leads to the loss of potential customers. So this design decision needs to be further considered. The solution could also be a compromise between the two ways.

Measure around the fullest part of your chest. Keep tape parallel with floor all the way around.

Take body measurements

For all measurements, pull the tape measure so that it sits on the surface of the skin, but doesn't compress the skin. You should be able to put a finger behind the tape, but no more than that. Please try to wear clothes that fit closely or wear nothing at all. It can be a little tricky to take some measurement on your own, so if possible, see if you can find a friend to help you.

Chest Around
99 cm

Shoulder Width
cm

Waist Around
cm

Wrist Around
cm

Bicep Around
cm

Arm Length
cm

Attention

Be carefule not to slope the tape

Be carefule not to swirl the tape

Back

Done, create garment sizes

With your elbow bent, measure from your shoulder point and follow your arm down to your wrist.

Take measurements

For all measurements, pull the tape measure so that it sits on the surface of the skin, but doesn't compress the skin. You should be able to put a finger behind the tape, but no more than that. Please try to wear clothes that fit closely or wear nothing at all. It can be a little tricky to take some measurement on your own, so if possible, see if you can find a friend to help you.

Chest Around
cm

Shoulder Width
cm

Waist Around
cm

Wrist Around
cm

Bicep Around
cm

Arm Length
cm

Attention

Start at where your arm bends

End around or just past your wrist bone

Back

Done, create garment sizes

figure 5.7 A new interface of the measuring guide

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Appendix B: Tasks walkthrough of existing online solutions

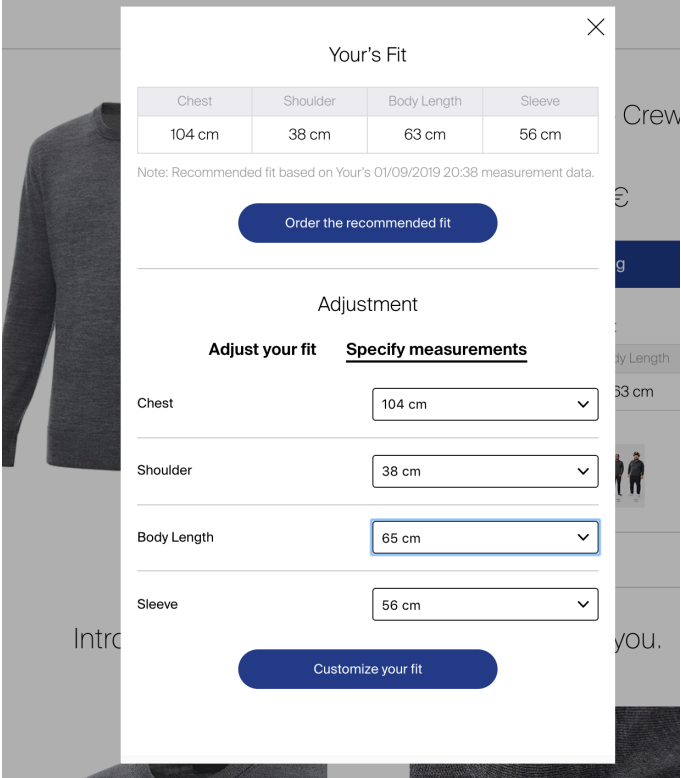## a) ZOZO

1. Get a recommended size
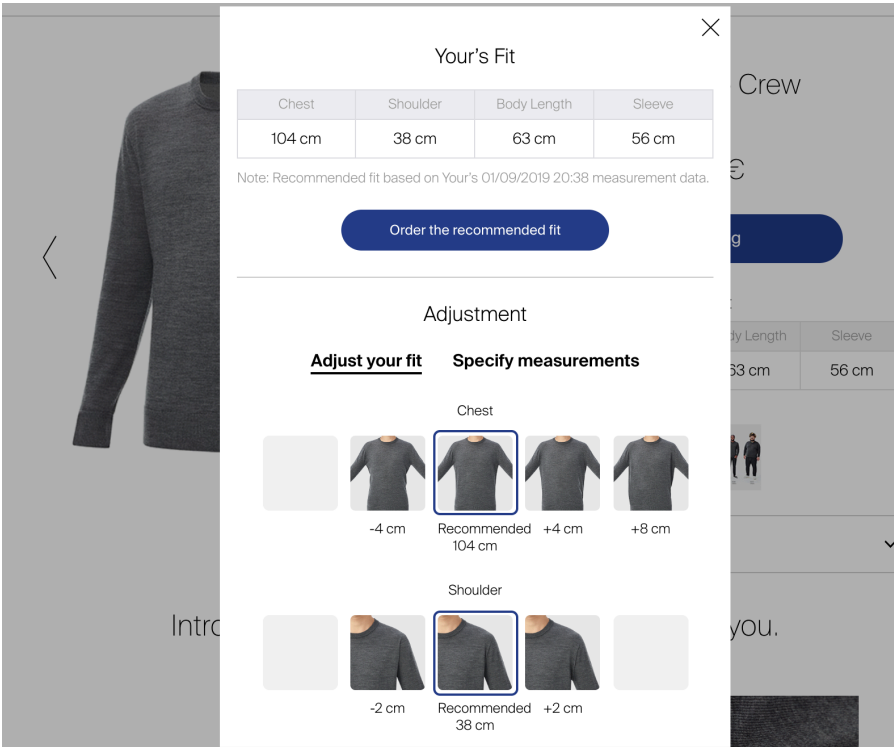
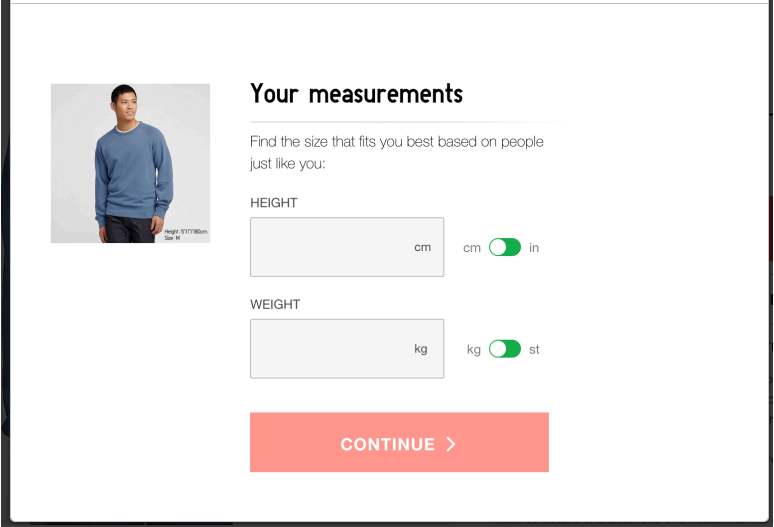### 2. further adjust preferred fit on different body parts
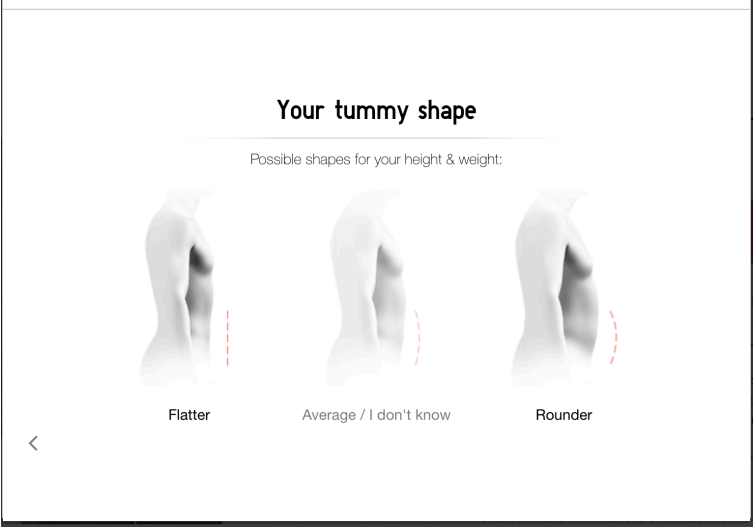

3. specify measurements
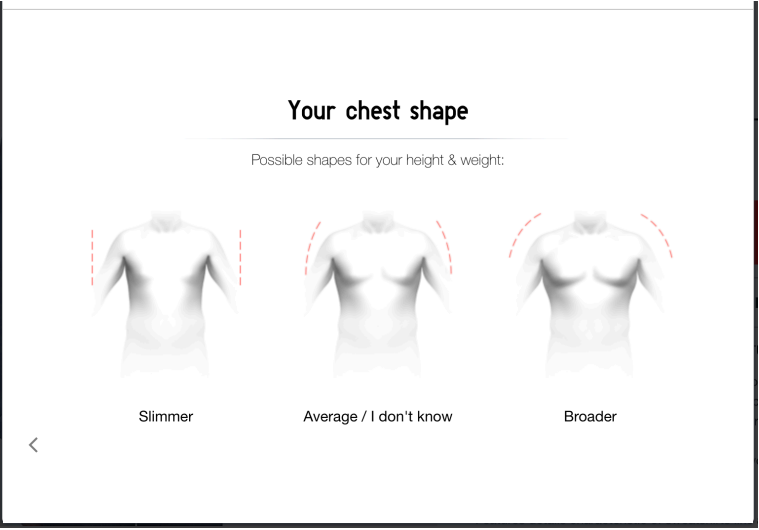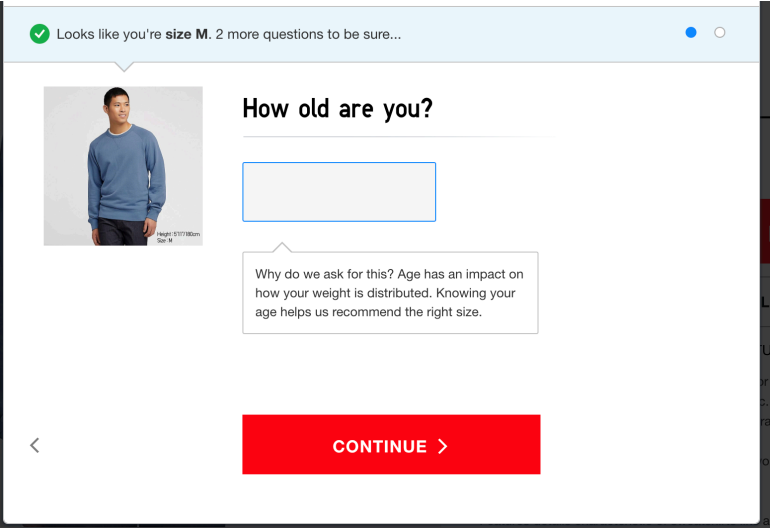

b) Fit finder

1. Input height and weight

2. Indicate one's (subjective) assessment on tummy shape

3. Indicate one's (subjective) assessment on chest shape

Your chest shape

Possible shapes for your height & weight:

Slimmer   Average / I don't know   Broader

4. Input age

Looks like you're size M. 2 more questions to be sure...

How old are you?

Why do we ask for this? Age has an impact on how your weight is distributed. Knowing your age helps us recommend the right size.

CONTINUE ›

5. Indicate one's fit preference

Looks like you're size M. Last question...

Your fit preference

I want this sweatshirt to fit...

SLIGHTLY LOOSE

‹ TIGHTER   LOOSER ›

CONTINUE ›

6. Get a recommendation of proper size

Size not available

L   71%   ✓

M   29%

Based on the purchases of thousands of similar shoppers, size L is your best fit. **Unfortunately, this size is currently not available.**

Edit info   CONTINUE SHOPPING ›
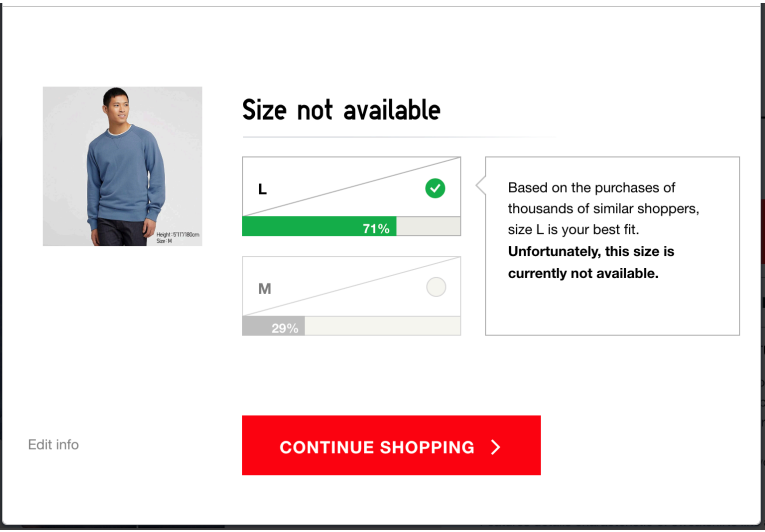
c) Bivolino

Input height, collar size, weight, age, fit

Sizing

measure. Your sleeve length is automatically adjusted

Toggle to imperial

Height: 186 cm

Collar size: 45 cm

Weight: 76 kg

Age: 22 years

Fit:

Regular Fit15

BIOMETRIC SIZING TECHNOLOGY
WARRANTY 100% SATISFIED
PATENT NR 2P1341427

If, as a new customer, you're not **100% happy** a 2nd shirt will be sent out free of charge and you get to keep the first shirt. So, **no returns!**
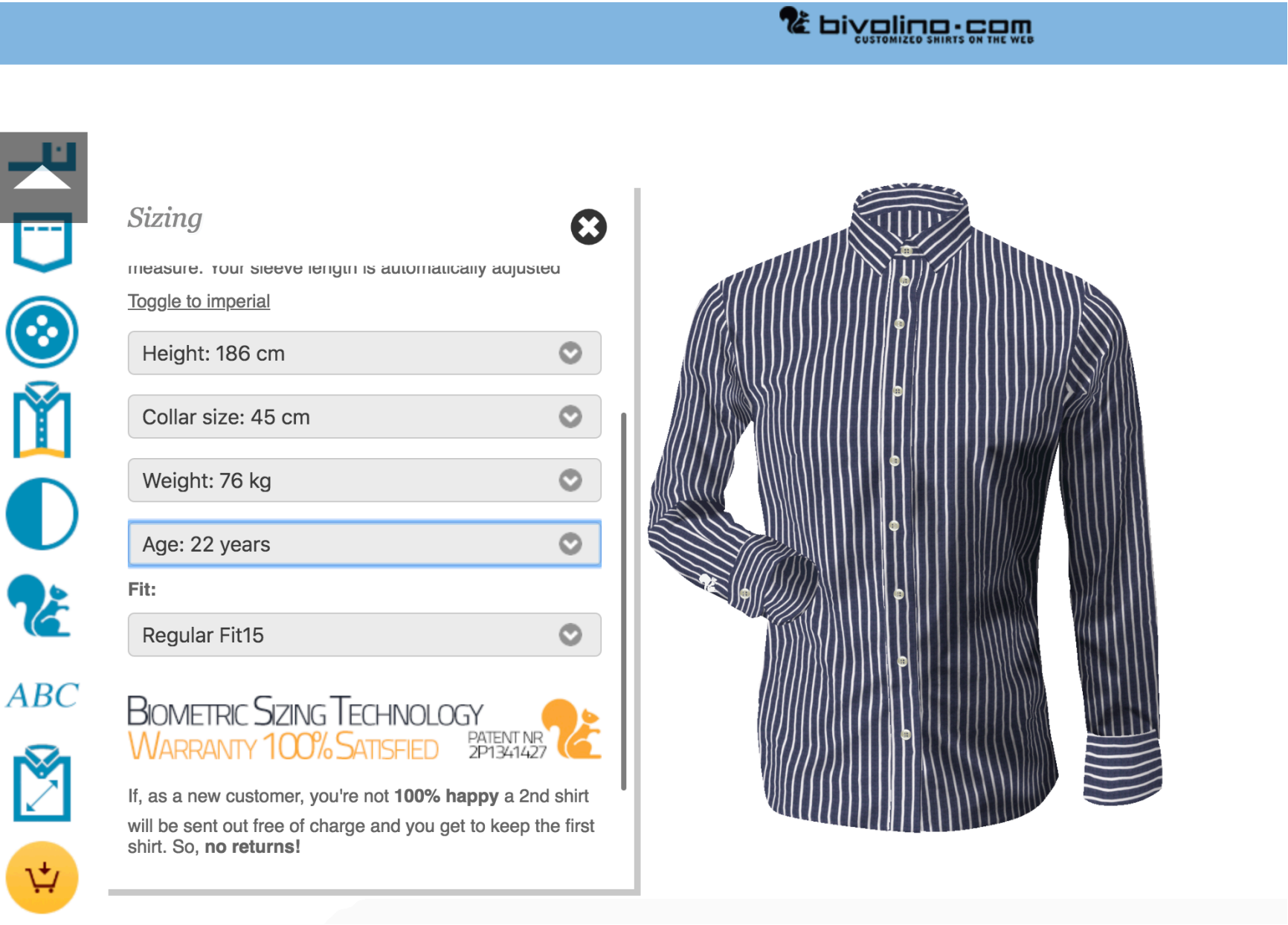
Appendix C: Material perception experiment

Procedure of the experiment
The steps of the session are as follows:
1. Participants agreed to take the test and provide information for research reasons.
2. Participants filled in basic information and their knowledge level of knitting.
3. They saw the virtual knitted fabric on computer screen.
4. They rated their perception on seven fabric properties and the overall quality.
5. They were given the real fabrics to touch and feel them.
6. They rated their perception again on seven fabric properties and overall quality based on real fabrics.
7. They answered some overall questions.
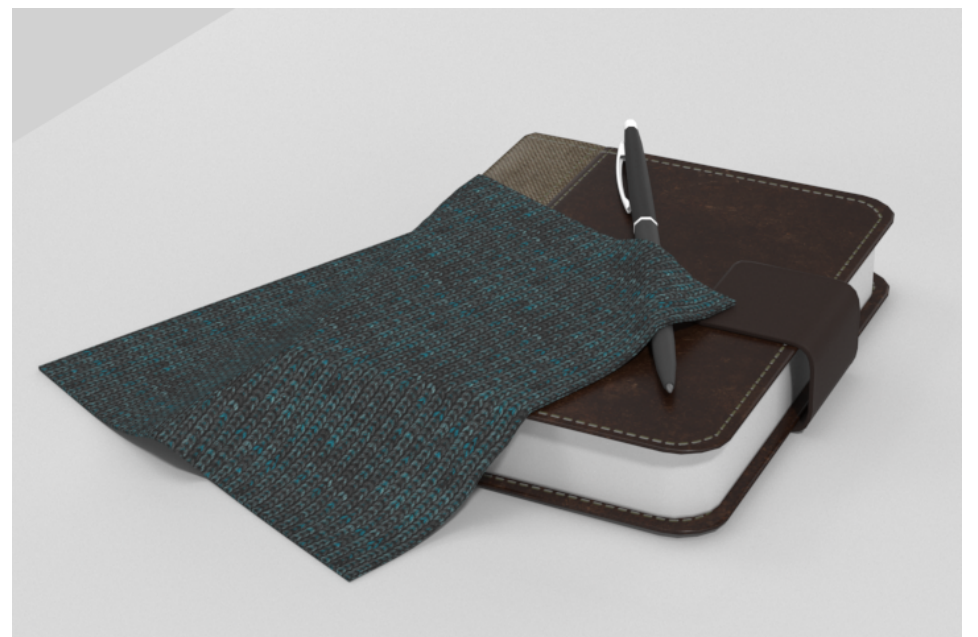
Images of the virtual fabrics

Questionnaire

Information collection

1. **Your information and inputs for this experiment will only be used for research reasons, in order to improve virtual garment visualization. (*please tick on the box)**

   ☐ I have read the text above

2. **Gender: Male / Female**

3. **Age:**

4. **How would you assess your knowledge level of knitting?**

   ☐ No knowledge   ☐ Shallow knowledge   ☐ Deep knowledge   ☐ Expert

Evaluating fabric properties

Imagine you are buying a knitwear online. The virtual fabric is what will be used to make the knitwear. Please rate your impression of the knitted fabric in terms of following properties.

Surface Property

Clean	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Hairy

Smooth	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Rough

Flexural Property

Soft	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Hard

Loose	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Tight

Perceived Temperature

Cool	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Warm

Bulk Property

Light	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Heavy

Thin	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Thick

Overall Quality

Poor	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10	Excellent

1. Does color influence your feelings on fabric properties? If yes, how?

☐ Yes. _____

☐ No

The raw data of ratings on all the properties and some comments

	clean/hairy			smooth/rough			soft/hard			loose/tight			cool/warm			light/heavy			thin/thick			poor/excellent		
	virtual	real	change	virtual	real	change	virtual	real	change	virtual	real	change	virtual	real	change	virtual	real	change	virtual	real	change	virtual	real	change
p1	3	2	-1	2	2	0	5	2	-3	5	2	-3	8	4	-4	7	2	-5	8	3	-5	9	9	0
p2	5	3	-2	4	4	0	5	3	-2	4	6	+2	6	3	-3	4	5	+1	6	4	-2	7	5	-2
p3	3	4	+1	3	5	+2	7	5	-2	7	5	-2	8	8	0	8	3	-5	8	3	-5	8	8	0
p4	2	6	+4	4	7	+3	5	3	-2	5	5	0	7	9	+2	5	9	+4	8	8	0	8	9	+1
p5	8	7	-1	5	7	+2	7	3	-4	4	3	-1	6	8	+2	7	3	-4	8	5	-3	7	8	+1
p6	3	3	0	6	4	-2	6	6	0	4	6	+2	7	5	-2	6	4	-2	5	4	-1	8	7	-1
p7	2	2	0	6	4	-2	7	7	0	8	4	-4	3	8	+5	6	3	-3	8	6	-2	7	6	-1
p8	2	3	+1	6	6	0	8	5	-3	3	3	0	6	4	-2	8	2	-6	3	2	-1	8	7	-1
p9	3	3	0	5	6	+1	6	5	-1	5	5	0	4	6	+2	7	4	-3	6	4	-2	7	7	0
p10	5	6	+1	4	4	0	4	3	-1	6	7	+1	7	6	-1	7	5	-2	6	3	-3	8	9	+1

	Does color influence feelings	biggest differences/is it important
p1	no	It feels much lighter. Depends on the weather, autum or spring
p2	no	
p3	no	real fabric feels thinner. I thought the virtual was heavy and thick(like a blanket)
p4	no	thickness. Yes
p5	no	It's less hairy than what I expected from knitwear
p6	yes, staalgrijs&turquais one looks more hairy	the stitches looks smaller than images. Yes
p7	yes, blue one looks more hairy and soft	virtual one looks tighter than real fabric. Yes
p8	yes, the second one looks most clean but a bit hard. The third one looks more hairy and	The weight. Real fabric is quite light while it looked heavier. Yes
p9	no	real fabric is softer and lighter. Yes
p10	yes, the dark one looks most smooth	thickness. The real fabric is thin. Yes

The change of ratings before and after seeing the real fabric

	clean/hairy	smooth/rough	soft/hard	loose/tight	cool/warm	light/heavy	thin/thick	poor/excellent
participant1	-1	0	-3	-3	-4	-5	-5	0
participant2	-2	0	-2	+2	-3	+1	-2	-2
participant3	+1	+2	-2	-2	0	-5	-5	0
participant4	+4	+3	-2	0	+2	+4	0	+1
participant5	-1	+2	-4	-1	+2	-4	-3	+1
participant6	0	-2	0	+2	-2	-2	-1	-1
participant7	0	-2	0	-4	+5	-3	-2	-1
participant8	+1	0	-3	0	-2	-6	-1	-1
participant9	0	+1	-1	0	+2	-3	-2	0
participant10	+1	0	-1	+1	-1	-2	-3	+1
average	+0.3	+0.4	-1.8	-0.5	-0.1	-2.5	-2.4	-0.2

Appendix D: questionnaire of Activity I. product page

Questions asked

website information

1. Overall, I got sufficient information of the knitwear from the website.

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agreee

2. Based on pictures/information of the knitwear, I feel it's trustworthy and reliable.

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

3. Based on pictures/information of the knitwear, I have the impression that it is of good quality.

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

Responses

1. Overall, I got sufficient information of the knitwear from the website.

6 responses

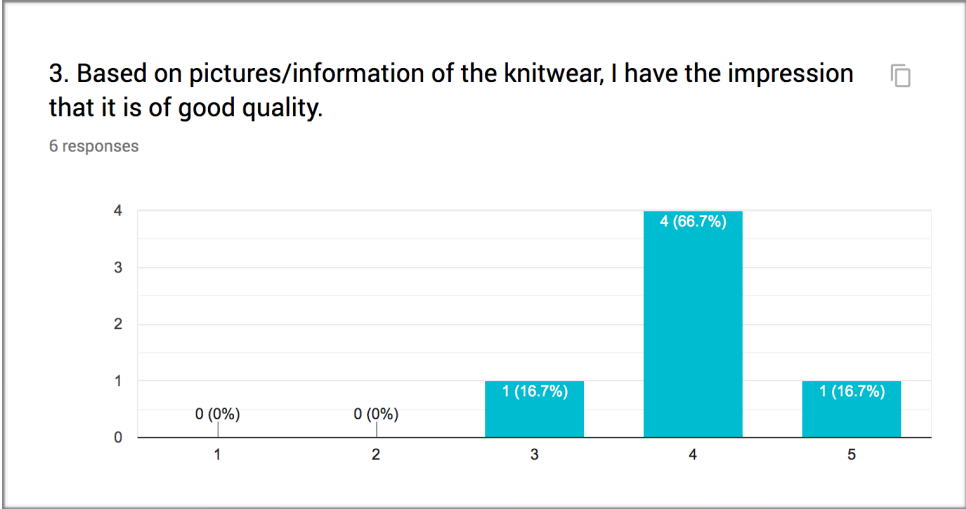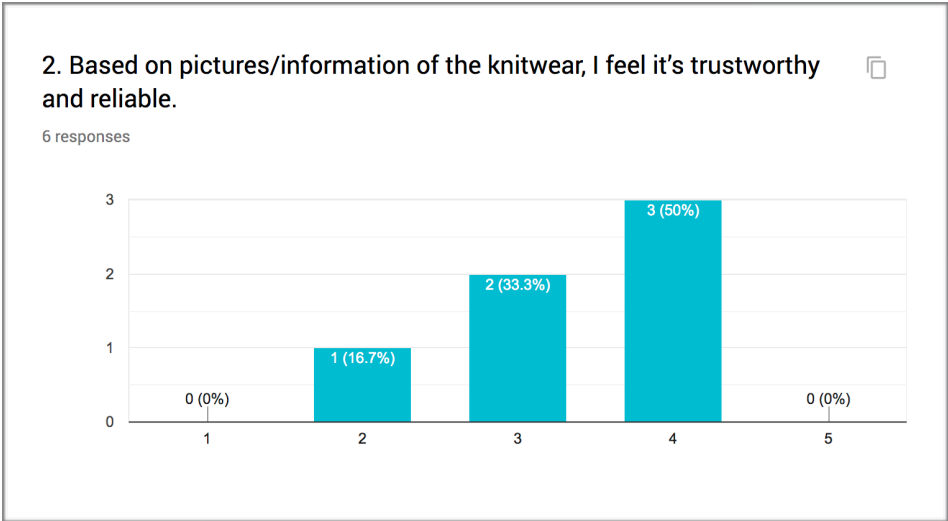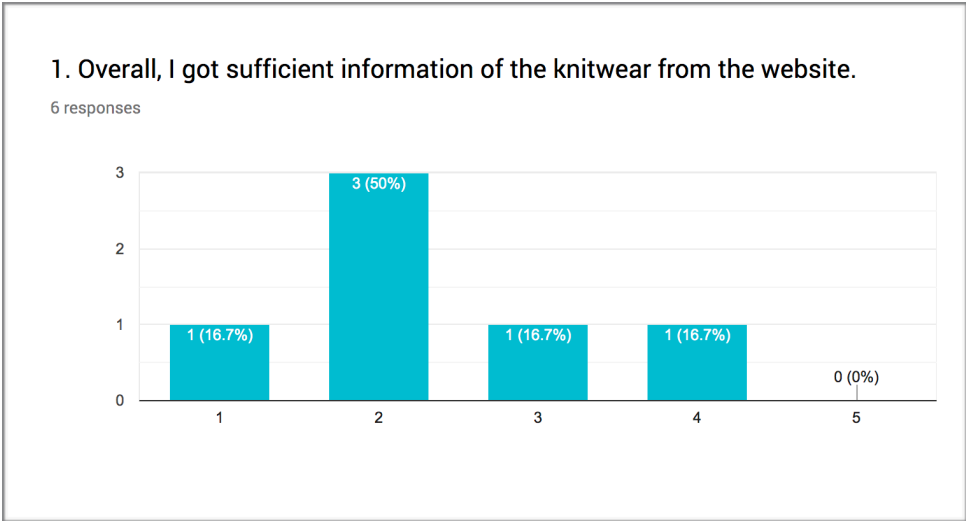2. Based on pictures/information of the knitwear, I feel it's trustworthy and reliable.

6 responses

3. Based on pictures/information of the knitwear, I have the impression that it is of good quality.

6 responses

Appendix E: questionnaire of Activity II. Deciding the garment sizes

Questions asked

1. It helps me imagine what I will look like wearing the knitwear

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

2. It helps me know the material properties and tactile feelings better

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

3. It helps me evaluate whether the size fits me

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

4. You have experienced the following interactions with the virtual scene. Please tick what you think is useful to evaluate the garment fit.

☐ Rotating the avatar

☐ Zooming in/out
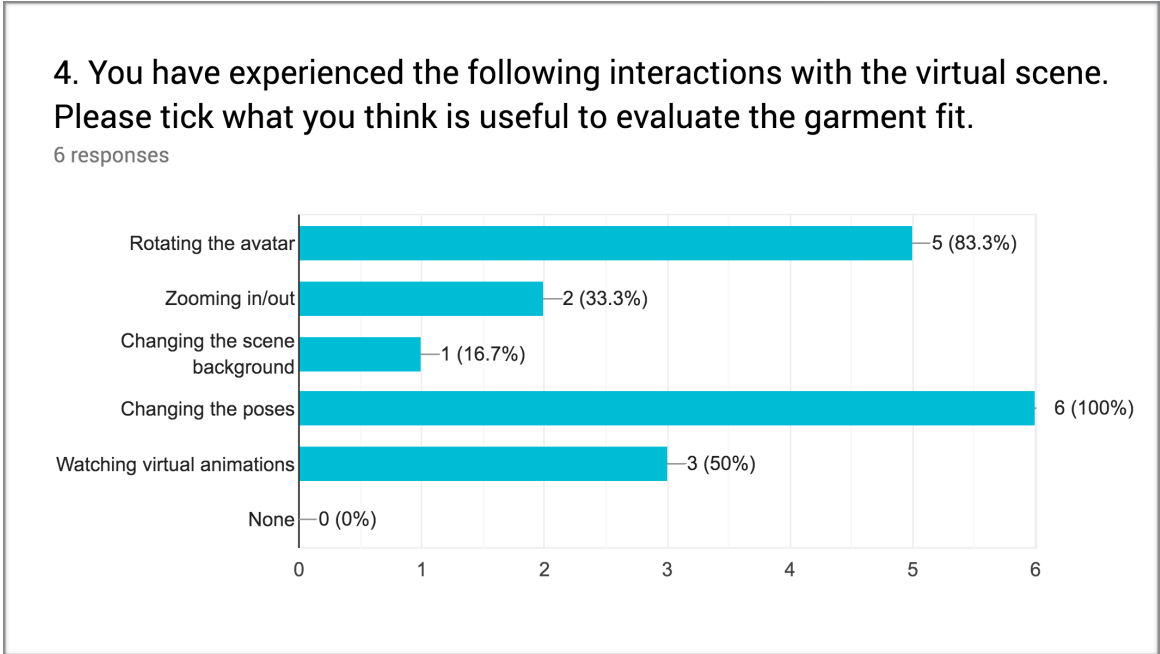
☐ Changing the scene background

☐ Changing the poses

☐ Watching virtual animations

☐ None

Responses

1. It helps me imagine what I will look like wearing the knitwear

6 responses

2. It helps me know the material properties and tactile feelings better

6 responses

3. It helps me evaluate whether the size fits me

6 responses

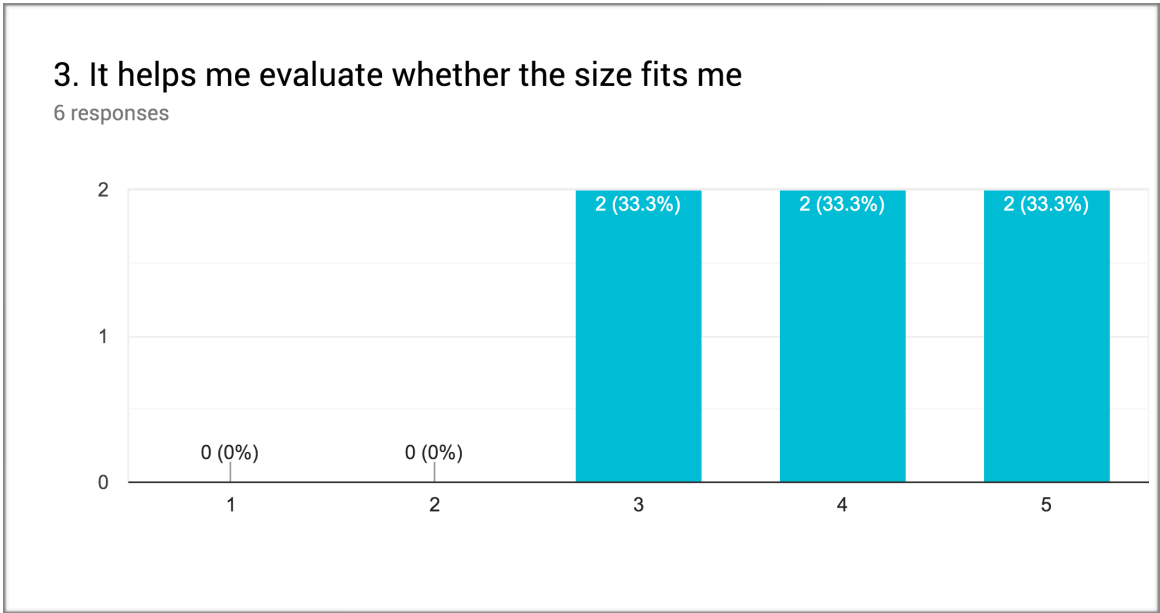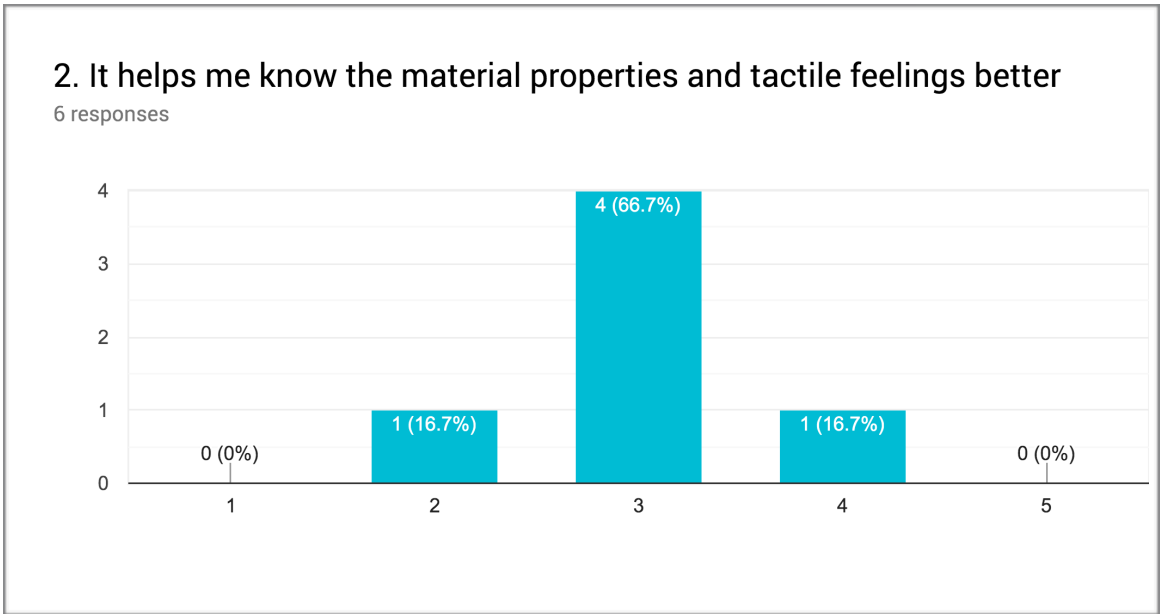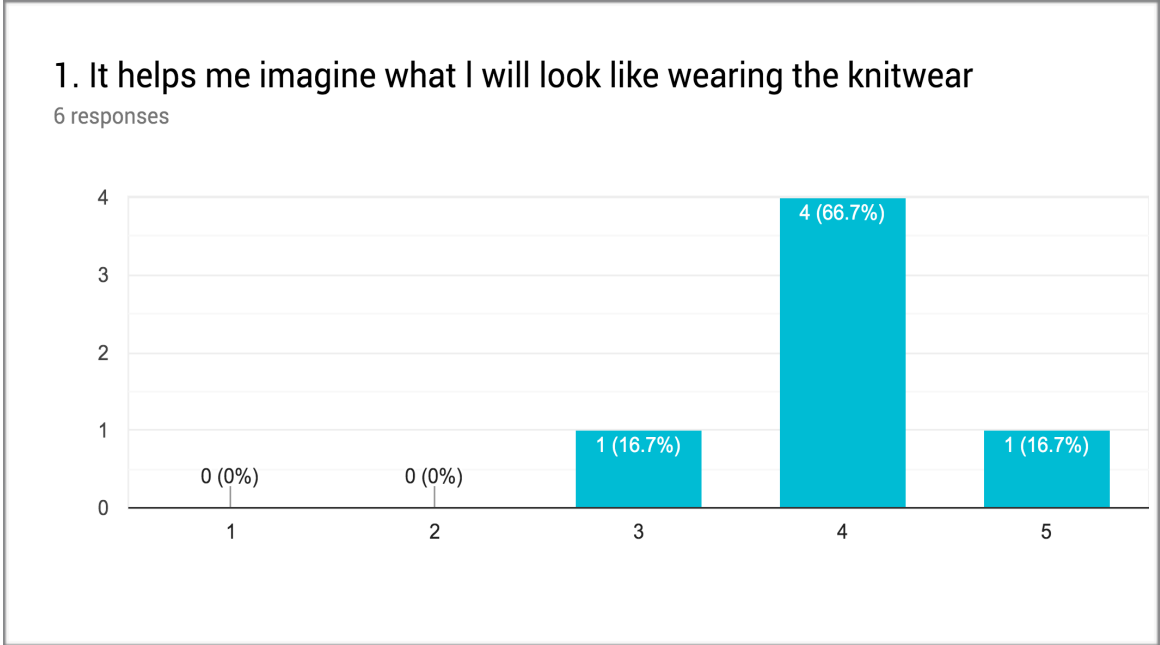## 4. You have experienced the following interactions with the virtual scene. Please tick what you think is useful to evaluate the garment fit.

6 responses

Appendix F: User test protocol

Before the session

Invitation

Emma and Leslie send invitation emails to participants, to introduce the company background and the purpose of the evaluation session. The email explains what we need from them and what they can expect from us. The email also introduces me (Wenjun) to participants as a TU Delft student graduating at Industrial Design on the customer journey for the company's product.

Make appointments with participants

I send emails to participants to make an appointment with them of the evaluation session. The session can be at IO faculty/ DOK center/TU Delft library. Participants use the link below to pick a date and time. Then I send a confirmation to them, giving a brief introduction about the session and suggesting them to bring a garment/sweater fit well as a reference.

Appointment link
https://docs.google.com/spreadsheets/d/13nIBY6w3rvJexls_js0ssV8-OaULXVpjYJjc3nqpOyQ/edit#gid=0

Have participants make their body measurements

I also send a document of measuring instruction with the email. It asks a few body measurements from them. Participants are asked to fill in the document and send it back to me at least 2 days prior to their appointmentments, so I can calculate recommended garment sizes and make personal virtual fitting images in advance. I use their self-reported measurements to make virtual avatars and garments to make the virtual fitting experience real. This part need to be prepared before the test due to the technical limitation that the images cannot be created in real time.

Conducting the session

Greet user and explain user testing procedure

The session starts with the introduction of the test purpose and the expectation for the session length and scope. To make participants feel more comfortable, I provide an overview of the session procedure and explain that I am testing the design and not them.

Greeting Script
"Hi [user's name]. I'm Wenjun with the graduation project in collaboration with the company Personalized Knitwear. At the moment the company is investigating how to set up a total on demand production chain. Today we are looking for ways to optimize the customer journey of the online purchasing process. This will be a test of the interface prototype of a website; we are not testing you. If you find something difficult to use, chances are that others will as well, so your feedback will help us to evaluate the components' design and to discover any issues we need to address. After the test, we will have some questions to ask you and we will have a discussion about the concept. The whole session will take about 45 minutes. We will answer any questions you have at the end of the session.

Have user sign consent form

Before the test a consent form is necessary to ensure that the participant affirms willingness (in writing) to participate in the study. I inform them that their actions on the laptop will be screen recorded and their information will be only used for internal purposes.

Hosting Script
"First I'll need you to sign this Consent Form. With your consent, I would also like to do a screen recording on your actions on the laptop to further assist our analysis. Information gathered today will be only used for internal purposes, and will be kept secure."

Conduct the test

To start the test, I tell the participant the task they need to complete by using the prototype and where they should start. Their task is to configure a personalized garment and finish the purchase until they check out. They are asked to speak all thoughts aloud as they go through the tasks.

Hosting Script

"Your task is to buy a personalized garment on this website until you check out. You start from the homepage which tells all the background information and company introduction. Then you need to enter the product page to continue the task. Please speak all your thoughts aloud as you go through the tasks. This helps us better understand why you are making certain choices.
Do you have any questions? Let's get started!"

During the test, I observe and take notes how the participant react on the given information and what are they saying and doing with the information. Their actions on the laptop are also screen recorded. For the participant, the steps they need to go through to finish the task are: Browse the homepage; Browse the product page; Choose a style; Choose colors; Decide sizes; Add to cart. To decide sizes, the website provides two options: Create custom sizes or Use standard sizes. The first one requires the participant to add their body measurements, choose preferred fit and try virtual fitting. The second one requires the participant choose S/M/L/XL with a size chart.

Have user complete a Post-test Questionnaire

After the test is completed, the participant grade subjective measures in a post-test questionnaire, so their either positive or negative response to the design can be learned. The questionnaire has a list of Likert statements that the participant is asked to evaluate by giving them a quantitative value (from 1 to 5), with level of agreement/disagreement being the dimension. This step helps to verify the quality of the design and identify issues with the user interface.

Questionnaire link
https://forms.gle/E5pSaBDBBwcPveMN6

Semi-structured discussion

After/During the questionnaire there is a semi-structured interview. Emma or Leslie may join the discussion together. The outline of the discussion:

- What is their feeling about the prototype; what did like and find attractive?

- What are key issues for success for an on demand production chain for knitted garments?

- How do they judge the sustainability claim of on demand production?

- What are the feelings about customized clothes, what size issues are important for the person?

- What are the feelings about online choosing your cloth? What is needed for this process?

- What are the feelings about the fact that garments cannot be send back?

- Suggestions on how to visualize the garments so that look and feel is well communicated;

Make body measurements

In the last part of the session, I make customers' body measurements again. So we have both self-reported measurements and real measurements to compare and check.

Conclude the session

To conclude the session, we thank the user for participating and let them ask any questions and debrief. We will offer them to buy the knitwear for € 99,- of which the normal retail price is €209,-.

After the session

Producing the knitwear

After the task, participants have made decisions on each configuration options of the personalized knitwear. Based on that result, the company will knit the garment in their studio if the participant would like to buy it. The production time is about two to four weeks.

Evaluation on the product

After participants receive their garments there will be an evaluation on the product. This is done by a survey by email, to learn customer satisfaction on the product compared with their expectation.

Test Metrics

System Usability Scale

The first part of a post-test questionnaire is SUS that measure the overall ease of use of a system. SUS is a reliable and valid evaluation tool of usability, which has become an industry standard with references in over 1300 articles and publications. It requires participant to score 10 usability items on a scale ranging from strongly agree to strongly disagree. The results can be interrupted into scores from 0 to 100. Based on research, a SUS score above a 68 would be considered above average and anything below 68 is below average.

Concept evaluation Questionnaire

The second part of a post-test questionnaire is composed of specific questions on the concept, especially on the experience of configuring process and virtual fitting part. This is to learn participants' appreciation and understanding on the website and different UI components.

Satisfaction on the personalized result

The third part of a post-test questionnaire asks question on customers' estimate and satisfaction on what they finally add into the shopping cart. The same question will be asked again after they receive the real product.

Likes, dislikes and recommendation

In the end of test session, there will be a semi-structured feedback session. The participant will be interviewed what they like or dislike about the design and if they have any comments or suggestions