David Cheng

Presenting Fabrics Online:

How to increase perception accuracy?

David Cheng

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Committee

Chair **Dr. M.W.A Wijntjes**
Department of Human Centered Design
Mentor **Dr. M.E.H. Creusen**
Department of Design, Organisation and Strategy

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Faculty of Industrial Design Engineering
Delft University of Technology

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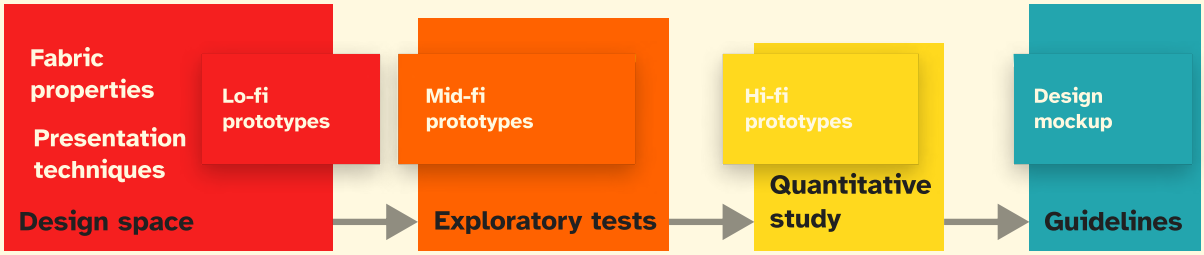
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Summary

Online fashion retail gives consumers access to a wide range of garments, but it also removes direct sensory interaction with the fabric. Properties such as thickness, stiffness, smoothness, glossiness, transparency, and colour appearance can be difficult to judge from standard product images alone. This can create a mismatch between the expectation formed online and the experience of the real garment after delivery.



This project investigated how online presentations can better communicate fabric properties, with the aim of helping consumers form more accurate expectations of the real fabric. The project followed an iterative design-research process. First, relevant fabric properties and possible presentation techniques were explored through literature, current retail examples, low-fidelity prototypes. Five directions were then developed into medium-fidelity prototypes: standard photographs, stereoscopic 3D photos, 3D scans, light sweeps, and interaction videos. These were examined in exploratory user tests to understand their perceived strengths, weaknesses, and practical limitations.


Standard photo


3D photo


3D scan


Light sweep

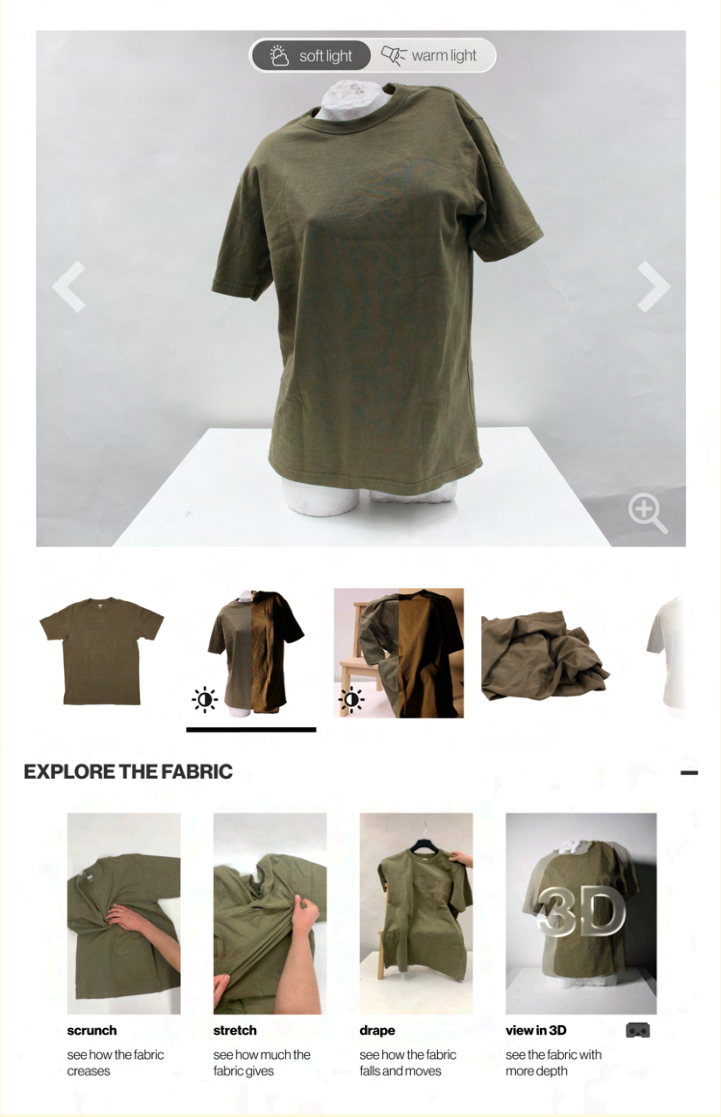

Interaction video

The exploratory tests showed that different presentation techniques supported different kinds of fabric judgments. Standard photographs provided a useful baseline impression, but did not communicate every property equally strongly. Interaction videos appeared promising for showing how fabric behaves under manipulation. Depth-based views helped reveal folds, structure and spatial form. Lighting variation could reveal surface, structure, and highlights, but could also make the garment look inconsistent across views.

Based on these insights, the quantitative study focussed on lighting as a more controlled and broadly applicable variable. The study compared garment presentations under *diffuse* lighting, *focus* lighting, and both lighting conditions. The results did not show a general improvement in perception accuracy or confidence when multiple lighting conditions were shown. Only colour lightness was significantly affected by lighting condition, with diffuse or combined lighting supporting more accurate judgments than focus lighting alone. Confidence also did not function as a straightforward indicator of accuracy; higher confidence was not associated with more accurate judgments. These results indicate that richer presentation is not automatically better. Additional views are only useful when they provide distinct cues and remain easy to interpret.



The project outcome is a set of design guidelines, illustrated through a product page mockup. The guidelines propose using a clear neutral view as a dependable reference point, adding complementary views only when they reveal distinct fabric cues, keeping comparable views visually consistent, making visual differences explicit, adapting presentation choices to the specific garment and difficult-to-judge properties, using interaction videos and depth-based views as optional support, and evaluating success through accuracy rather than confidence alone. The main contribution of the project is therefore not one superior presentation technique, but a practical framework for selecting and combining visual cues in ways that help consumers form expectations that better match the real fabric.



Introduction

1.1 Background and relevance

Online retailing has become a major channel for the sale of consumer goods, including fashion. Buying clothing online has become increasingly common, with clothing, shoes, and accessories forming the most frequently purchased online goods category in the EU in 2024 (Eurostat, 2025). This trend was strengthened by the COVID-19 pandemic (OECD, 2020), when physical retail was restricted (Eurostat, 2022). As a result, online fashion shopping has become an important part of contemporary retail practice.

At the same time, the online shopping experience fundamentally differs from shopping in a physical store. Online retail offers convenience and a large assortment, but it cannot provide the same sensory interaction as in-person shopping (Citrin et al., 2003; Silva et al., 2021). This is especially relevant for clothing; garments are evaluated on their visual appearance, but also on how they fit, feel, and behave when worn (Boardman & McCormick, 2022).

One way fashion retailers currently deal with this limitation is through generous return policies (Saarijärvi et al., 2017). Consumers may order garments, inspect and try them on at home, and return them if they fail to meet expectations. However, a retail system that relies on returns has important drawbacks. For consumers, returning products requires extra time and effort and may involve uncertainty pending refunds (Martínez-López et al., 2022; Stöcker et al., 2021). For retailers, returns involve logistical, financial, and administrative cost as well as the risk that returned goods may lose resale value or need discounting, reconditioning, or disposal (Frei et al., 2020; Stöcker et al., 2021). In addition, transport, packaging, and product waste associated with returns have an environmental impact (Frei et al., 2020; Roichman et al., 2024).
A key reason for returns is that the delivered garment does not match the expectation formed during the online purchase (Saarijärvi et al., 2017). This mismatch can concern multiple aspects of the product, including fit, colour, material quality, and fabric properties (Baytar et al., 2020; Creusen et al., 2025; Saarijärvi et al., 2017). In this project, the focus lies specifically on the fabric properties: qualities such as stiffness, thickness, smoothness, glossiness, and transparency, which contribute strongly to how a garment is experienced, but may be difficult to judge from a standard online presentation (Creusen et al., 2025; Jang & Ha, 2023).

The challenge of communicating fabric properties online is closely related to the role of touch in fabric perception (Creusen et al., 2025; Peck & Childers, 2003). Whereas online shopping relies primarily on vision, assessing fabrics in person is normally a multisensory interaction (Atkinson et al., 2013; Overmars & Poels, 2015; Wu et al., 2011). Consumers may be able to recognise broad material categories visually (Fleming et al., 2013), but more subtle tactile and mechanical properties are much harder to judge without touching the fabric (Atkinson et al., 2013; Jang & Ha, 2021). As a result, online presentations may lead consumers to form inaccurate expectations of the garment they will receive. Improving the communication of fabric properties is therefore a relevant design challenge, as better presentation may support more informed purchase decisions and reduce expectation differences between the online presentation and the real garment (Creusen et al., 2025).

1.2 Project framing

This project takes on the challenge of communicating fabric qualities in online fashion retail. More concretely, it focusses on improving how accurately important fabric properties can be perceived from an online presentation, compared to how those properties are experienced when handling the real garment. By reducing the mismatch between online impressions and the physical experience, the project aims to support more informed purchase decisions and help reduce returns.

The project builds on earlier research into the perception and communication of textile qualities. Prior studies have shown that the fabric judgments depend on multiple perceptual cues (Atkinson et al., 2013; Petreca et al., 2016; Wu et al., 2011; Xiao et al., 2016), and have suggested that future work further investigate and refine methods for presenting fabric qualities. Some relevant directions were interactive

visual depictions, as investigated by Orzechowski et al. (2011), and hand interaction videos, as studied by Shen (2018), Wijntjes et al. (2019), and Creusen et al. (2025).

The project was guided by the following overarching design goal:

Design an **online presentation for fabrics**
to improve the **perception accuracy** of **important properties**
for **consumers in online retailing**.

Within the project, perception accuracy is the primary evaluation principle. This refers to the degree to which judgments of fabric properties based on an online presentation match those made when the real garment is physically assessed. A presentation was considered more successful when the difference between those two judgments was smaller. In other words, the project aimed to improve the alignment between the a fabric's online impression and the experience of the real material.

1.3 Scope and approach

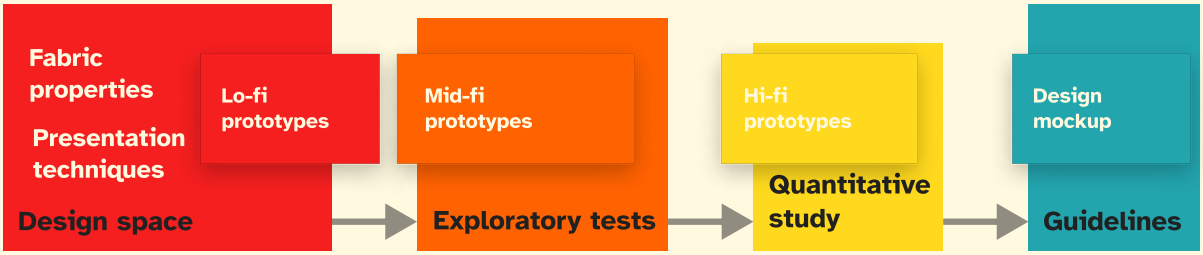
To address this design goal, the project was scoped as a research project focussed on the online communication of fabric properties of existing garments. The project was exploratory in nature. Its goal was not to produce a final, ready-to-implement commercial design concept, but to investigate and evaluate promising approaches for improving online fabric property communication. Rather than focussing on garments as a whole, the project specifically addressed the perception of the fabric itself. The emphasis therefore lay on fabric properties including thickness, glossiness, and transparency (Creusen et al., 2025), rather than on how the garment is constructed from those fabrics. Although sizing, fit, and style are also important factors (Boardman & McCormick, 2022; Chrimes et al., 2022; Eckman et al., 1990), they fall outside the scope of this project, as improving their communication would require conceptually different design directions that would be better addressed in a separate project. Additionally, the project mainly considered visual and interactive communication, rather than haptic technologies or broader service- or system-level interventions.

The project was approached as an iterative design-research process. It began with an exploration of the relevant fabric properties and of possible presentation techniques. Based on these explorations, a set of low-fidelity prototypes was created as a quick and practical way to investigate a range of design directions. Promising techniques were then refined into medium-fidelity prototypes, which were used in exploratory user tests. These tests gave insight into the different strengths and weaknesses of the techniques. Finally, the most relevant findings were taken into a more focussed quantitative evaluation.

This sequence was chosen to move from a broad understanding of the problem space towards increasingly specific and testable design decisions. Early exploratory phases were used to map the design space and identify promising directions, while later phases were used to evaluate them in a more structured way. The project thus combines open-ended design exploration with empirical testing in an iterative process in which prototypes were used to collect insights, which in turn informed further prototyping.

1.4 Report structure

The remainder of this report follows the project phases. Chapter 2 explores relevant fabric properties and presentation techniques. Chapter 3 describes the broad exploratory user testing phase. Chapter 4 presents the more focussed quantitative evaluation. Chapter 5 discusses the resulting design implications, and Chapter 6 concludes the project.



2 Fabric properties and presentations

Having framed the project and design goal, the next steps are to clarify which properties need to be communicated and which presentation approaches might help convey them. Exploring this design space will provide a foundation for generating and testing concepts.

2.1 Fabric properties: what needs to be communicated?

In online fashion retail, consumers cannot physically touch or manipulate the garment before purchase. As a result, they must rely on the online presentation and the (visual) means it affords to form an impression of the fabric and its qualities. To improve online fabric presentation, it is necessary to first determine which fabric properties are important to communicate.

Fabric hand
A useful concept in this context is *fabric hand*: the way a fabric is experienced when handled and perceived by a person. Fabric hand encompasses the holistic impression and is often communicated through descriptive words, especially by non-experts (Ciesielska-Wróbel & Van Langenhove, 2012). Although this impression is holistic, it can also be approached through more specific descriptive attributes (Philippe et al., 2003; Petreca, 2013).
For this project, it was useful to break the impression down into a set of more clearly defined fabric properties. This made it easier to identify what an online presentation should communicate, and to design prototypes and tests aimed at exploring those qualities more systematically.

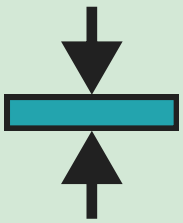
Objective and subjective assessment
Fabric properties can be assessed in multiple ways. On one hand, they can be described through objective measurements, for example with standardised textile evaluation systems like the Kawabata Evaluation System that quantify mechanical, surface-related, or other parameters (Ciesielska-Wróbel & Van Langenhove, 2012). Such methods offer consistency and calibration to defined reference standards. On the other hand, fabrics can also be assessed through subjective human judgment; people interpreting fabric hand through their own sensory experience (Sülar & Okur, 2007).

For this project, the subjective perspective is the more relevant one. Since the aim is increasing consumer satisfaction by matching expected properties with experienced properties upon receiving the real fabric, the subjective judgment is more directly relevant.
While objective measuring systems like the Kawabata Evaluation System can be valuable in industry and research for their standardisation, (Ciesielska-Wróbel & Van Langenhove, 2012; Sular & Okur, 2007), for the purposes of this study they would remain an indirect substitute for the human sensorily experienced fabric hand.
Earlier studies have also noted that objective measurements do not always correspond well to the way fabric hand is actually experienced by people (Chen et al., 2015). Since this project focuses on perception in a consumer context, the emphasis here is on the properties as they are judged by people, rather than only as they are measured instrumentally.

Identifying relevant fabric properties
Relevant fabric properties were synthesised from literature. This literature review was not meant to be fully exhaustive, but to establish a structured inventory of the fabric properties that occur in discussions of perception and evaluation. This was done with a practical project intent: the aim was to arrive at a set of properties that were distinct, understandable, and feasible to investigate in the next project phases. The reviewed sources were examined for qualities used to describe, assess, or compare fabrics. Because different authors don't all address the same properties and often use different terms for similar qualities, equivalent terms were identified and matched where possible. The overview below therefore presents a project-specific synthesis of the properties that were identified.

Fabric properties

form and mechanical behaviour properties



Thickness

How thin or thick one layer of the fabric is

thin - thick

found in
Atkinson et al. (2013)
Creusen et al. (2025)
Grinevičiūtė et al. (2005)
Jang & Ha (2021)
Soufflet et al. (2004)



Weight

How light or heavy the fabric is

light - heavy

found in
Creusen et al. (2025)
Grinevičiūtė et al. (2005)
Jang & Ha (2021)
Moody et al. (2001)
Petreca et al. (2015)
Xiao et al. (2016)



Stiffness

How much the fabric resists bending or deformation

limp - stiff

found in
Atkinson et al. (2013)
Creusen et al. (2025)
Grinevičiūtė et al. (2005)
Jang & Ha (2021)
Moody et al. (2001)
Petreca et al. (2014)
Soufflet et al. (2004)
Xiao et al. (2016)



Elasticity

How much the fabric stretches when pulled

not stretchy - stretchy

found in
Atkinson et al. (2013)
Creusen et al. (2025)
Grinevičiūtė et al. (2005)
Jang & Ha (2021)
Moody et al. (2001)



Creasability

How easily the fabric forms and retains creases when folded or compressed

crease-resistant - prone to creasing

found in
Grinevičiūtė et al. (2005)
Moody et al. (2001)

optical and colour properties



Glossiness

How matte or shiny the fabric surface appears

found in
Creusen et al. (2025)
Fleming et al. (2013)
Xiao et al. (2016)

matte - glossy



Transparency

How see-through the fabric appears

found in
Creusen et al. (2025)
Fleming et al. (2013)
Jang & Ha (2023)

opaque - transparent



Colour lightness

How dark or light the colour of the fabric appears

dark - light



Colour shade

The exact colour shade of the fabric



Warmness of touch

How cool or warm the fabric feels to the touch

found in
Atkinson et al. (2013)
Creusen et al. (2025)
Fleming et al. (2013)
Grinevičiūtė et al. (2005)
Moody et al. (2001)
Petreca et al. (2015)

cold - warm

surface properties



Softness

How compressible or yielding the fabric surface is

hard - soft

found in
Creusen et al. (2025)
Fleming et al. (2013)
Grinevičiūtė et al. (2005)
Petreca et al. (2013)
Soufflet et al. (2004)
Xiao et al. (2016)



Smoothness

How even or irregular the fabric surface is

rough - smooth

found in
Atkinson et al. (2013)
Creusen et al. (2025)
Fleming et al. (2013)
Grinevičiūtė et al. (2005)
Petreca et al. (2013)
Soufflet et al. (2004)
Xiao et al. (2016)



Fragility

How delicate or easily damaged the fabric appears

sturdy - fragile

found in
Creusen et al. (2025)
Fleming et al. (2013)

Classification of properties

The overview presents the set of 13 properties selected for the exploratory phase of this project. Although the literature discusses fabric perception using a broader and partly overlapping range of terms, the set shown here reflects a project-specific synthesis and selection of the properties. In arriving at this set, the properties that were found in literature were considered from multiple perspectives: how frequently they appeared, whether they were conceptually distinct from other properties, how important they were expected to be in consumers' evaluation of garments, how plausible it would be to improve their conveyance through online presentation, and how testable they would be within the scope of the project. This made it possible to define a manageable set of properties that were most relevant for the next phase of the project.

The literature organises properties in different ways: Petreca et al. (2013), for example, distinguish physical, mechanical, surface, and thermal properties, while Soufflet et al. (2004) identify emerging dimensions from user descriptions. In this project, however, the selected properties were grouped pragmatically into form and mechanical behaviour properties, optical and colour properties, surface properties. Warmness of touching and fragility were standalone properties that didn't quite fit other categories. These categories were not used as a strict analytical framework but as a loose structure to keep related properties together and for presenting and interpreting them in a logical order during the later studies.

Colour properties

The colour-related properties require some further explanation. In the literature, colour is often treated more broadly as a single property, sometimes described as colour or colourfulness (Creusen et al., 2025; Fleming et al., 2013). For this project, the aim was not to assess whether a fabric appeared colourful, but whether its actual colour was conveyed accurately in digital presentations. Different aspects of colour appearance were therefore treated more granularly. **Colour shade** was used to capture whether the presented apparent colour matched the colour of the real fabric, and **colour lightness** was included separately because prototyping revealed that digital presentations could specifically distort the perceived lightness or darkness of the fabric (Section B.3).

Subselection for quantitative study

As noted above, these 13 properties were used for the exploratory user tests described in Chapter 3. For the later quantitative study of Chapter 4, the set was narrowed further and slightly adjusted to a subset of seven properties: glossiness, transparency, thickness, smoothness, colour lightness, colour warmness, and colour saturation. These were considered most relevant, most plausibly influenced by lighting, and most suitable for controlled visual assessment. The reduction was also done for practical reasons: including all 13 properties in both the in-person baseline and online quantitative studies would have substantially increased participant burden, study duration, and analytical complexity.

2.2 Presentation techniques: how could it be communicated?

Now that the relevant fabric properties have been identified, the next question is how these properties can be communicated in an online retail context. Different presentation techniques and technologies provide different information. Some may be more suitable for conveying colour and optical characteristics, while others may be better able to communicate drape and deformation. This Section will first examine the contemporary standard way of garment presentation, and then explore alternative techniques to understand which directions might be of added value.

2.2.1 Current presentation

To establish a practical reference point for the project, a small exploratory scan of garment product pages from current fashion retailers was done. The scan included 24 product pages from six retailers: three multi-brand and three brand-specific. For each retailer, four product pages were selected: two from the women's section and two from the men's. Within the tops category, the first two products were selected that were plain and did not have distinctive features such as prominent prints, unusual construction, or decorative elements. This selection was intended to keep the focus on fabric presentation more than garment construction or prints. The scan was not done was a comprehensive study of current practice, but as an indicative overview of the kinds of (visual) information that commonly appear in online garment presentations.

The presentation elements were fairly consistent across the 24 reviewed pages, varying somewhat in number and completeness both within and between retailers. The product pages generally contained garment-only photos, multiple model images, and textual information. Close-up views were present on half of the pages, and video and views with different lighting or context views were rare. Some descriptions about fabric properties were available, but these were mostly limited to the word "soft" appearing in the description.

***Table 2.1**. Count of presentation elements found in the exploratory scan of 24 garment product pages.*

Presentation element	Pages present (*N* = 24)	%
Garment-only photo	21	88
Model/mannequin view	20	83
Additional model views	20	83
Close-up view	12	50
Clearly different context/lighting view	4	17
Zoom function	24	100
Model video	1	4
Fabric composition text	24	100
Fabric property description text	9	38

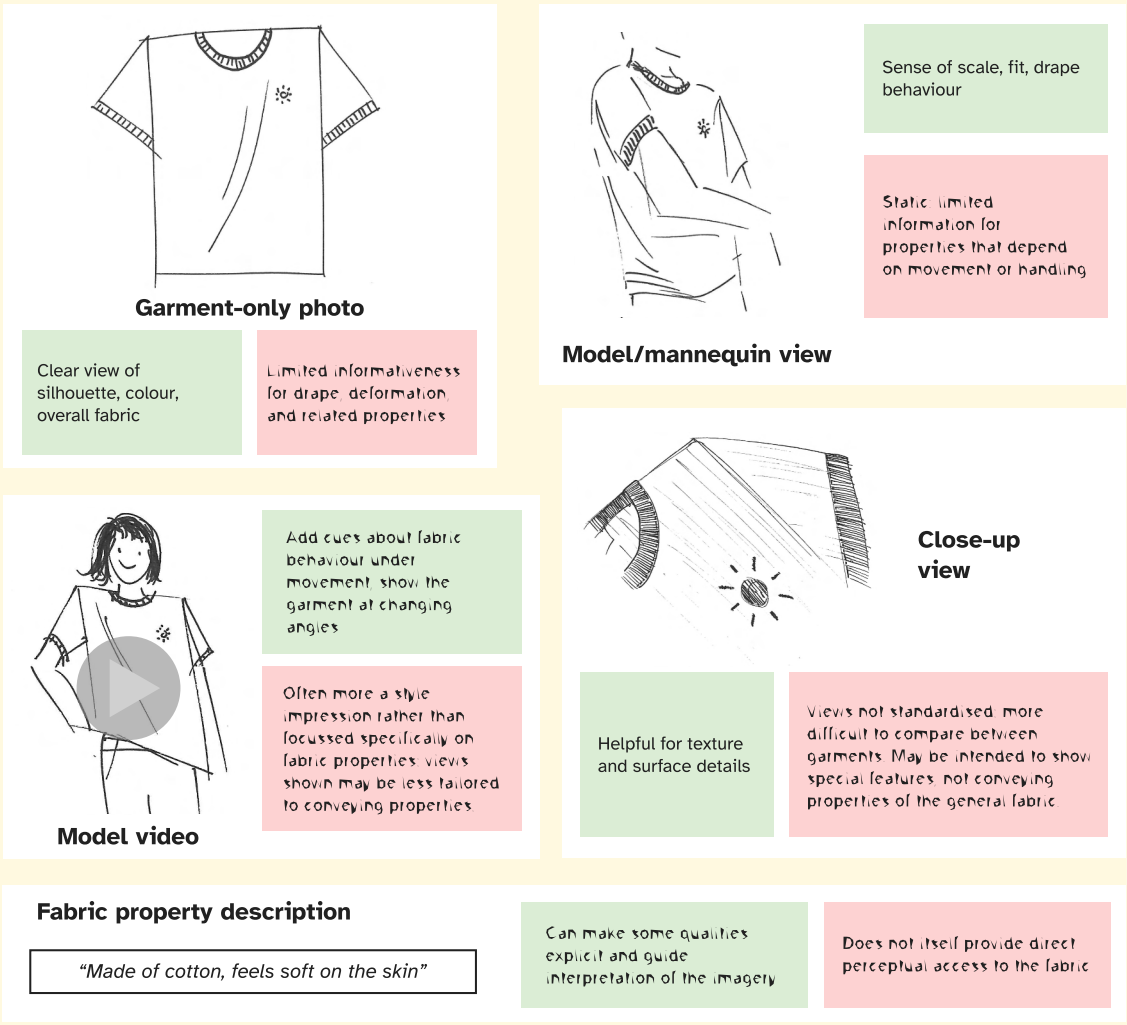


***Figure 2.1**. Common elements identified in the scan of current online garment product pages, including the likely strengths and weaknesses of these elements for communicating fabric properties.*

Figure 2.1 illustrates the elements found. The visual imagery is generally clear and consistent, and appears effective for communicating general appearance. However, it seems to offer more limited support for judging more specific fabric properties. Many of the additional images are variations of the same model view from different angles, which may help to communicate style and fit, but do not necessarily provide different information about the fabric itself or how it behaves under different conditions. In the exploratory tests described in Chapter 3, only photographs were included in the "standard" condition, as videos were made as a separate condition. Also, because this project is focussed on visual means, the text description element is not further investigated, even though it may help to make certain qualities explicit and could help guide how images are interpreted.

2.2.2 Alternative/emerging techniques/technologies

Besides examining the contemporary standard presentation, I conducted a design-oriented exploratory scan of possible presentation techniques to understand what kinds of alternative presentation techniques already exist or are emerging. This was not a comprehensive cataloguing of all possible technologies nor was the purpose to directly select techniques for prototyping, but it was an exploration that served primarily as a **way to map the design space** of possible ways of presenting fabrics. By building a broader understanding of the range of possibilities, it became easier to ideate concrete prototype directions in an informed way. While investigating these techniques, attention was paid to the kinds of property cues they could theoretically provide, their likely usefulness and interpretability for

consumers, their plausibility as consumer-accessible technologies, and their feasibility within the scope of this project.

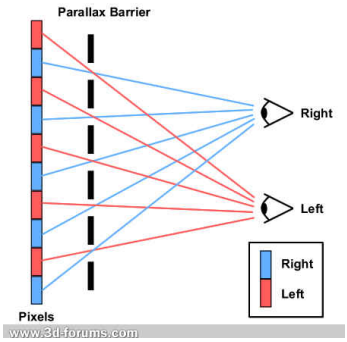
Depth-based techniques

One group of techniques aimed to add depth and spatial information to the presentation. This was relevant because a fabric's underlying physical properties influence both how it drapes visually and how it feels when touched; meaning that folds, drape, and shape can provide clues about qualities like thickness and stiffness (Yuan et al., 2017). This idea is also supported by earlier work showing that additional three-dimensional folding cues can improve fabric judgment accuracy, while flattened fabric views mainly reveal textural information (Xiao et al., 2016). Enhanced depth perception might aid how well these shapes are conveyed. The explored examples included, among others, stereoscopic and depth-based image techniques like wigglegrams, anaglyphs, headset-based 3D viewing, and synthesised views.

Within this group, relatively accessible image-based techniques were promising, as they could add depth information without requiring a fully simulated fabric model or highly specialised technology. Techniques like Neural Radiance fields did not seem to produce imagery of sufficient quality, and such views might be better directly recorded rather than synthesised. I further explored wigglegrams, anaglyphic 3D images, and later stereoscopic 3D photos in low and medium fidelity prototypes (see Appendix B and C).



Neural Radiance Fields generate new viewpoints from 2D photographs.
Note. Images from Stephens (2022).



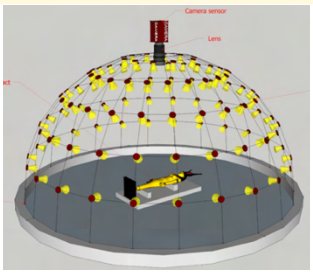
Stereoscopic 3D viewing can be achieved in multiple ways, including a parallax barrier and lenticular displays. The principle for these kinds of depth viewing is to show separate images to the left and right eye.
Note. Images from Ian (2009).

***Figure 2.2**. Examples of depth-based techniques: Neural Radiance Fields (left) and stereoscopic 3D viewing (right).*

Lighting-based techniques

A second group focussed on changing illumination to accentuate properties that may be hidden in static, evenly lit photographs. Surface reflections, shadows, and highlights can provide cues about the shape, texture, glossiness, and indirectly stiffness or thickness through the way the folds are visually defined. Xiao et al. (2016) also found that colour contributed more when fabrics were shown with folds than when they were flat, and suggest that folds and colour together can help viewers distinguish between similar fabrics. Techniques that were investigated in this direction included reflectance-based imaging approaches and more accessible forms of controlled lighting variation.

Some highly specialised techniques (like the full Reflectance Transformation Imaging (RTI) process, Smithsonian Museum Conservation Institute (n.d.)) seemed too complex or too far removed from a recognisable consumer-facing presentation to be useful in consumer-facing applications and in this project. However, the broader principle that changing light direction can reveal different material qualities was still relevant. This insight informed the prototyping of light-based presentations, including the light sweeps described in Appendix B.



Reflectance Transformation Imaging setup, which involves capturing an object many times with different lighting angles and processing this data into a detailed surface map.
Note. Image from Hameeuw (2021).

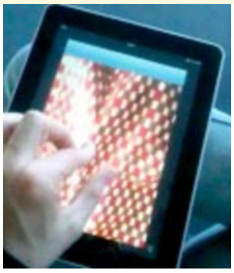


Presentation of a jar with a movable light source.
Note. Image from Xie (2016).

***Figure 2.3**. Examples of light-based techniques: Reflectance Transformation Imaging (left) and a movable light source interaction (right).*

Motion and interaction-based techniques

A third group consisted of techniques that show fabric behaviour through movement and interaction (Figure 2.4). This direction was especially relevant for properties that have to do with deformation over time, like elasticity. Earlier work had already suggested that people can extract information about material qualities from observing another person's exploratory hand movements (Yokosaka et al., 2018), and that some types of videos, including handling gesture videos specifically, can help communicate some textile qualities (Creusen et al., 2025). For that reason, hand interaction videos were also included in the prototyping endeavours (see Appendices A and B) and later carried forward into the exploratory tests in Chapter 3.



"iShoogle" touchscreen-interactive fabric presentation.
Note. Image from Atkinson *(2013).*



Hand interaction still from a video.
Note. Image from Shen (2018).

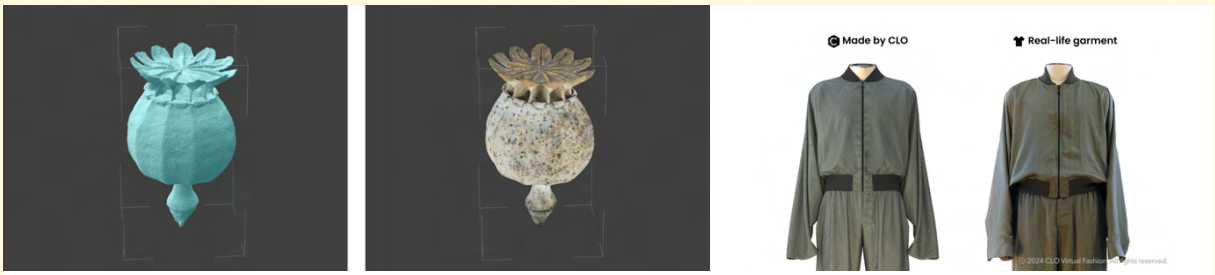
***Figure 2.4**. Examples of motion and interaction-based techniques: iShoogle (left) and hand interaction video (right).*

3D models and simulated fabrics

The fourth group involved digital 3D models of fabrics, including models constructed from 3D scans, computational reconstruction from 2D images, and cloth simulation (Figure 2.5). These approaches offer the possibility of freely viewing a garment from any angle and, in the case of simulated cloth models, it would also be possible to control the pose and movement. More generally, interactive object presentation may also be valuable because user-controlled motion can support more active exploration of a product. Prior work suggests that such control can improve understanding of experience-related product attributes, although this does not in itself guarantee better communication of specific fabric properties (Orzechowski et al., 2011; Overmars & Poels, 2015).

However, the principle of 3D models also raised important limitations. A digital scanned 3D model may capture geometry or texture well, but not necessarily both. Some forms of reconstruction rely partly on interpolated or estimated geometry, which makes it uncertain how accurate the resulting depiction is.

For fully simulated cloth models, the challenge is even greater: such a model is only useful for consumer presentation if its visual appearance and physical behaviour correspond well to the real garment. Recent work on digitally rendered fabrics shows that simulation parameters including digital folds and specular roughness can bias the perceived sheen, colour, and even material classification of fabrics (Haghzare et al., 2023). If the simulated properties do not match the real fabric closely enough, the presentation risks communicating the wrong material qualities instead of clarifying them. This would require substantial modelling effort, raising the question whether it would not be more effective to use the real garment, which would guarantee accurate behaviour. For this reason, fabric simulation was not prototyped but 3D scanning was explored in the lo-fi (Appendix B) and mid-fi (Appendix C) prototypes.



Macro-photogrammetry builds a 3D object from macro photos from multiple angles and focal distances.
Note. Image from Zmejevskis (2023).

Example of a CLO simulated fabric, mainly aimed at designers rather than consumers.
Note. Image from CLO Virtual Fashion (n.d.).

***Figure 2.5**. Examples of 3D models and simulated fabrics: macro-photogrammetry (left) and CLO 3D (right).*

Directions to investigate further

Taken together, these explorations showed that several directions were worth exploring further: techniques that added depth cues, lighting variation, or movement and interaction. These directions were taken forward into low-fidelity prototype explorations, which are described in detail in Appendix B.

2.3 From exploration to prototyping

The explorations in this Chapter clarified both what needs to be communicated in online fabric presentation and which kinds of techniques might help to communicate it. The literature on fabric properties showed that fabric perception can be described in a multitude of ways and involves a range of mechanical, surface, optical, and other qualities. To have a relevant, feasible, and defined set of measures to address in the project, a subset of properties was selected for further exploration in the next Chapter.

The subsequent exploration of presentation techniques indicated that standard online garment presentation provides useful information about overall appearance and some surface detail, but seems to offer more limited support for properties that depend on depth, illumination, or movement. It may thus be desirable to develop presentation forms that improve upon these.

To investigate these directions more concretely, several depth-based, lighting-based, and motion-based techniques were explored in low-fidelity prototype form. These prototypes, shown in Figure 2.6, were intended to develop a more practical understanding of their possibilities and limitations before moving to more refined stimuli to show users. The "lo-fi" prototypes are documented in Appendix B. The insights gained from both the literature review and these early experiments then informed the more refined medium-fidelity prototypes (Appendix C) developed for the exploratory tests described in Chapter 3.

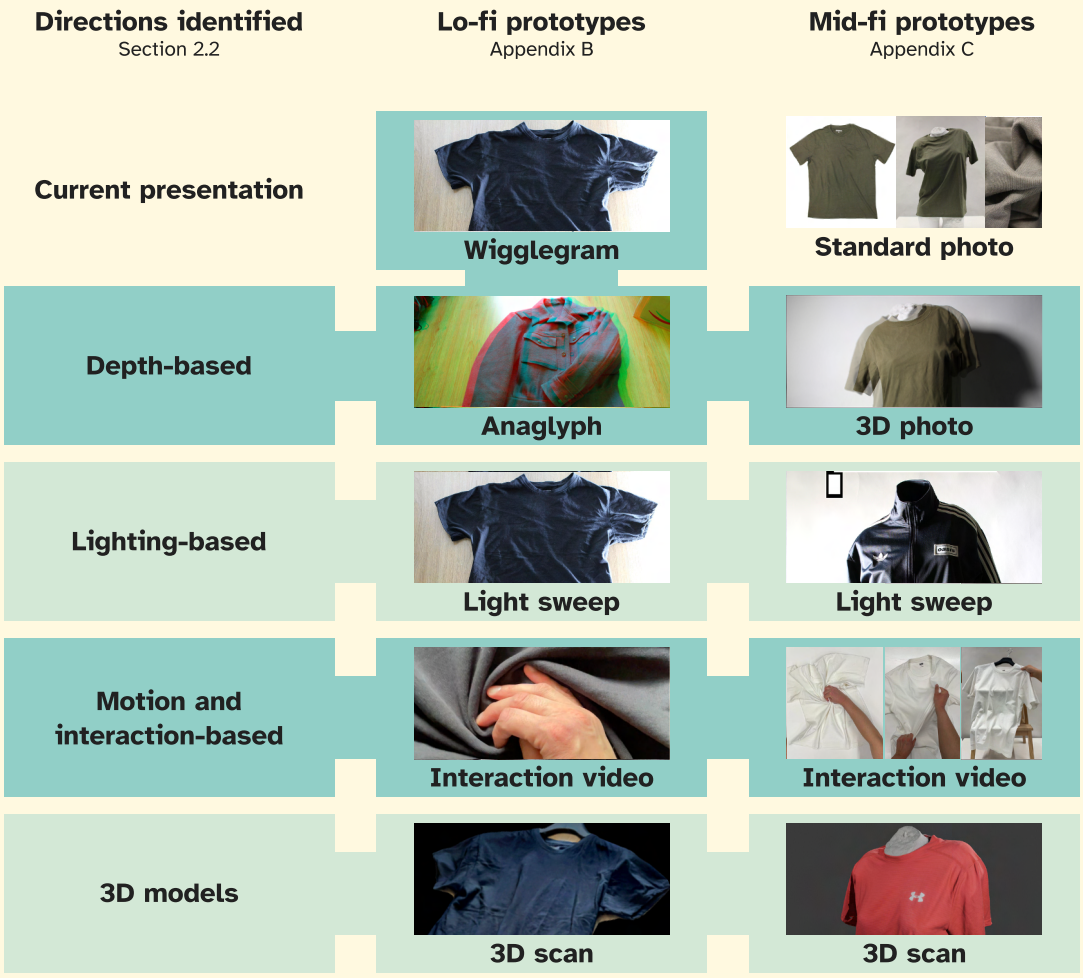


***Figure 2.6**. Overview of how the identified presentation directions were translated into the techniques used for lo-fi and mid-fi prototypes.*

3 Exploratory tests

3.1 Purpose and role in the project

Building on the exploration of presentation techniques in Chapter 2, the five selected presentation directions were first developed through low-fidelity prototype explorations documented in Appendix B. These early prototypes were used to gain practical design and production insights for each techniques, what kinds of fabric information they seemed able to reveal, and which limitations needed to be addressed. Based on those insights, the five basic presentation directions were iterated into medium-fidelity prototypes, documented in Appendix C, that were suitable for users to compare in this Chapter's tests. This phase was not intended as a rigorous or definitive evaluation of finished design concepts. Instead, its purpose was to generate design-relevant insights for the next stage of the project.

The exploratory tests were used to examine the perceived strengths and weaknesses of different presentation methods, to identify which fabric properties appeared difficult to convey, and to reveal additional considerations for further design. This way, the exploratory phase served as a bridge between the broader exploration of possible presentation directions of Chapter 2 and the more focussed evaluation that followed in Chapter 4, helping to identify a direction that could be investigated more systematically.

3.2 Method

3.2.1 Study design

The exploratory tests consisted of face-to-face sessions in which participants evaluated several presentation techniques in a structured but relatively informal setting. The techniques were standard photographs, 3D photos, 3D scans, light sweeps, and interaction videos (see Figure 2.6 and Appendix C). The sessions combined fixed response formats with space for thinking out loud and open feedback, so that both comparative judgments and richer qualitative insights could be collected. Responses were therefore documented using response tables and audio recordings.

In each session, participants encountered a series of technique-garment combinations. For each trial, one presentation technique was shown for one garment, after which the real garment was presented and evaluated in relation to that technique. After all techniques had been shown, participants ranked the presentation methods overall from best to worst.

Since the aim of the exploratory phase was broad insights rather than formal comparison, the stimulus-participant combinations were chosen to maximise coverage of the available prototype variations. Some techniques contained internal variants (Figure 3.1); for example, original versus self-made standard photographs, different lighting versions for the 3D photos, and different display modes for the 3D scans. These variants were distributed across participants rather than repeated systematically for quantitative comparison. As a result, some variants were shown only once or a few times, but across the participant group all main garment-technique combinations and all broader variant types were represented.



***Figure 3.1**. Some techniques contained internal variants, for example original brand images and variously lit versions.*

Each participant was shown all five presentation techniques once. The order of techniques was varied across participants, and within a session no garment was shown twice. Across all sessions, all techniques, all garments, and all variant types were included. This partial-coverage approach was also chosen to keep the sessions manageable. A pilot comparison of alternative test formats suggested that asking participants to compare multiple techniques for the same garment at once was cognitively demanding and yielded less useful feedback. Evaluating one technique-garment combination at a time proved more manageable and produced clearer responses.

3.2.2 Participants

Eight participants took part in the exploratory test phase. Participants were recruited through convenience sampling from the researcher's own network, including design students. A small sample was considered appropriate for these tests, as this phase was meant to generate qualitative design insight rather than statistically generalisable findings. The chosen sample size also allowed the prepared garment-technique combinations to be covered across participants.

3.2.3 Materials

Garments

A set of eight garments was selected for the tests (Figure 3.2). To support comparison across properties, the garments were selected to provide variation across all 13 properties included in this study. The specific garment type was not a key variable in this phase. The selection was limited to tops for practical reasons, as these could be presented in a similar way on the mannequin. Prior to testing, the researcher judged the set to include garments representing relatively lower and higher values on each property.



***Figure 3.2**. Garments used in the exploratory tests.*

Presentation techniques

Five presentation techniques were included: standard photographs, 3D photos, 3D scans, light sweeps, and interaction videos (Figure 3.3). Some techniques included multiple internal variants, such as different lighting versions or display modes, which increased the number of possible stimuli. These techniques were selected because they represented various ways of communicating fabric qualities, including static photographic presentation, added depth cues, interactive viewpoint control, changing illumination, and visible deformation over time. Together, they reflected the most relevant directions identified in the preceding exploration of presentation possibilities discussed in Chapter 2. Each technique is described in more detail in Appendix C.

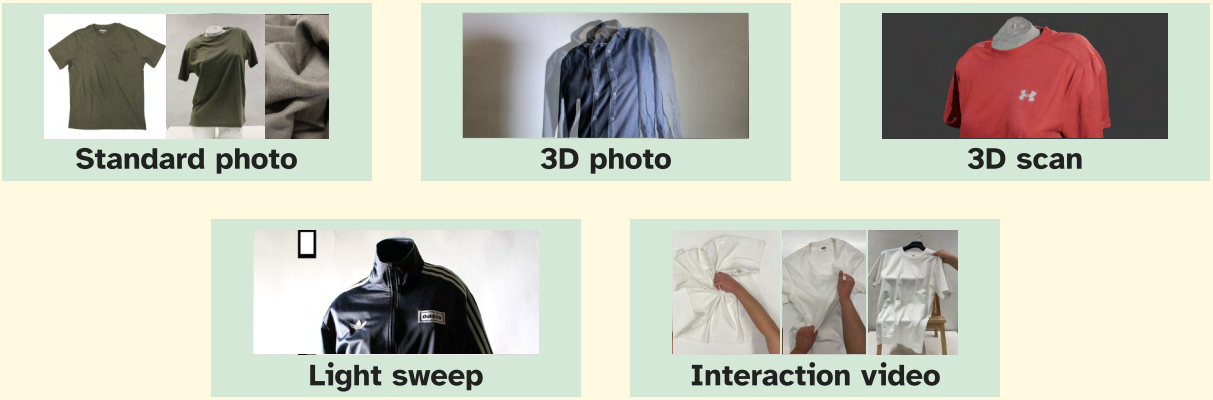
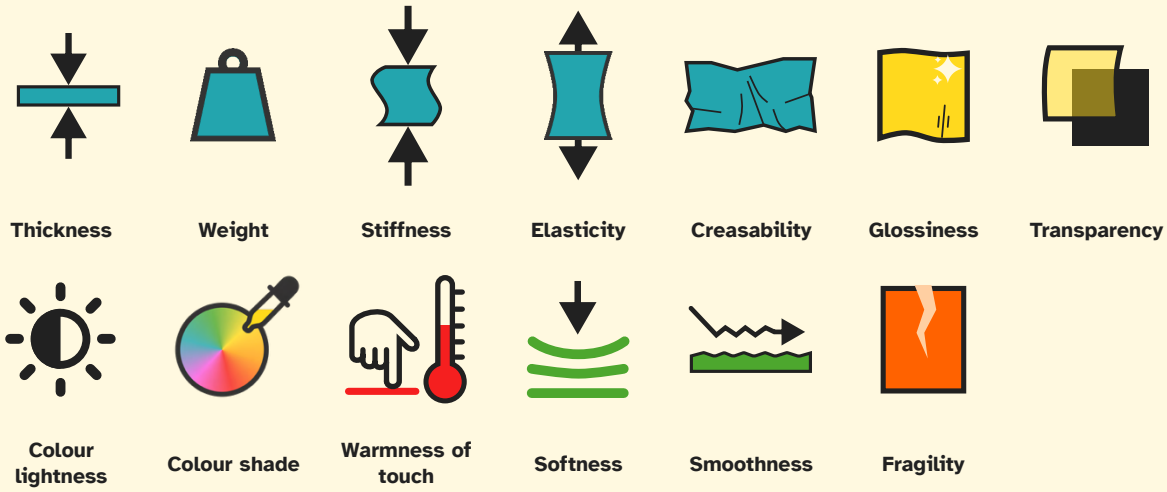


***Figure 3.3**. Presentation techniques used in the exploratory tests.*

Properties

Participants evaluated how well each presentation conveyed a set of fabric properties. The task was therefore not to rate the actual value of the property itself (e.g. how thick the fabric is), but to judge how effectively that quality was communicated by the presentation.

The following 13 properties were included:



These properties were selected because they covered a broad range of mechanical, optical, surface, and other qualities that had emerged as relevant in the earlier exploration of Chapter 2.

Colour lightness was treated separately from colour shade because, during prototype development, it became clear that lightness posed a distinct challenge from hue while capturing the imagery. Dark garments in particular posed a recurring challenge: increasing exposure made surface detail more visible, but could also make the garment appear lighter or greyer than it did in reality.

3.2.4 Procedure

At the start of each session, participants received a short introduction to the purpose and format of the test. The list of fabric properties was shown and briefly explained to ensure that participants understood what each property referred to during the evaluation.

Then, participants were shown a series of presentation techniques, one at a time. For each trial, a participant first viewed one presentation of a garment and was given time to inspect it until they indicated that they had formed an impression. They were then handed the real garment to freely view and handle, while the digital presentation remained available. The participants completed a response table indicating how well the presentation conveyed each of the listed fabric properties on a five-point scale. Participants were encouraged to verbalise their thoughts throughout the session and were asked follow-up questions about what they thought the presentation communicated well, what seemed to be missing, and how the presentation might be improved. This provided qualitative feedback to complement the fixed ratings. After all five techniques had been presented, participants were asked to rank the presentation methods overall from best to worst.



***Figure 3.4**. A participant comparing a 3D photo to the real fabric while filling in the answer sheet.*

3.2.5 Analysis approach

Because the exploratory phase was intended primarily as a design tool, the results were analysed descriptively rather than through formal statistical testing. The fixed response tables were used to identify broad patterns in how well different presentation techniques were perceived to convey different fabric properties, while the overall rankings provided a rough indication of participant preference across techniques. In addition, participants' verbal comments were used to interpret these patterns and to identify recurring strengths, weaknesses, ambiguities, and improvement opportunities.

The results were considered at multiple levels: per presentation technique, across properties, and across garments. This made it possible to distinguish between observations that seemed related to the presentation method itself and those that appeared to depend more strongly on the specific garment or variant shown. The purpose of this analysis was not to draw definitive conclusions about technique effectiveness, but to generate practical insights for prototype refinement and for the design of the subsequent quantitative study.

3.3 Results

This Section presents the main findings from the exploratory tests, combining patterns from the response tables with observations from participants' comments.

3.3.1 Overall participant preferences

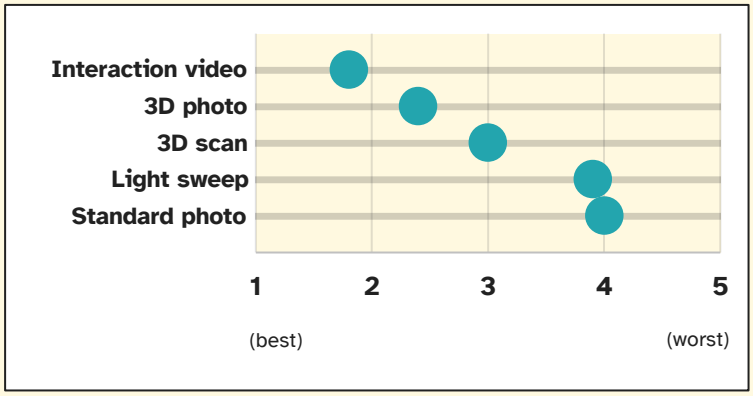


***Figure 3.5**. Average rankings of each presentation technology given by participants in the exploratory tests (N = 8).*

After viewing all five presentation techniques, participants were asked to rank them overall from best to worst. Figure 3.5 shows the resulting mean ranks, with a lower score indicating a more favourable ranking. Overall, the interaction videos were ranked most favourably. They were consistently placed near the top and were never ranked lower than third place. The 3D photos also performed relatively well, although participant opinions were somewhat more mixed. The 3D scans showed the greatest variation in ranking, tending to be judged either near the top or near the bottom rank. Light sweeps and standard photographs were generally ranked lower, with standard photographs receiving the lowest mean rank overall.

These rankings should be interpreted as an indication of participant preference rather than as direct evidence of actual perception accuracy. Because participants were explicitly asked to rank the techniques from most to least preferred, the results reflect their overall impressions of the presentation formats as a whole, rather than as an aggregation of the property-specific ratings discussed later in this Chapter. Still, the pattern suggests that participants generally appreciated techniques that offered a richer or more distinctive overall impression of the fabric. Interaction videos, for example, may have been experienced as especially informative as they included a lot of information: three different gestures, movement, and human handling. 3D photos may have benefitted from their stronger sense of folds and shape. By contrast, standard photographs may have been experienced as comparatively limited, while light sweeps may have occupied a more ambiguous position: potentially informative for certain aspects, but less informative for others and as a result less consistently preferred as an overall presentation format.

3.3.2 Insights per presentation technique

This Section summarises the main patterns that emerged from the response tables and participants' comments.

Property	Standard	3D photo	3D scan	Light sweep	Interaction video
Thickness	0.9	1.3	1.1	1.2	1.1
Weight	1.0	1.4	0.9	0.9	0.8
Stiffness	1.2	1.2	1.1	1.2	1.4
Elasticity	0.4	1.0	0.6	-0.1	0.8
Creasability	1.2	1.5	1.4	1.0	1.4
Glossiness	1.0	1.3	1.0	0.9	0.3
Transparency	0.8	1.1	1.6	1.4	1.1
Colour lightness	0.9	0.7	-0.1	1.1	1.4
Colour shade	0.9	1.0	0.5	0.4	1.1
Warmness of touch	0.9	1.1	0.9	0.9	1.1
Softness	1.0	0.6	0.6	0.9	0.6
Smoothness	1.1	0.4	1.1	0.7	0.9
Fragility	1.2	1.3	1.5	0.9	1.1

***Figure 3.6**. Mean perceived conveyance score per property and presentation technique in the exploratory tests. Scores are based on the five-point response scale recoded from -2 (poorly conveyed) to +2 (well conveyed). Darker cells indicate more positively rated conveyance. The averages are based on slightly different numbers of observations between cells, due to the unequally balanced presentation of prototype variants across participants.*

Figure 3.6 provides an overview of how positively each presentation technique was rated for conveying each fabric property. Overall, most average scores fall on the positive side of the scale. This suggests that all techniques were generally able to communicate at least some useful impression of the fabrics. At the same time, the figure also shows that the techniques differed in which properties they appeared to support most strongly. The patterns per technique are discussed in more detail below.

The averages summarise a small number of responses and can hide disagreement between participants. A moderately positive mean may reflect shared appreciation of a technique, but may also result from divided opinions averaging out.

Standard

The "standard" photographs generally provided a clear and familiar representation of the garments. Most properties were judged moderately positively, suggesting that this format already provided a solid baseline representation of the garments. Its highest average scores were for stiffness, creasability, and fragility, which happened to be similarly well conveyed by other techniques.

Participant comments suggest that clear, conventional photographs with a sufficient range of views already communicate a substantial part of the garment impression. Nevertheless, these photographs were rarely seen as especially strong.

> *"This is the most basic, but it's pretty clear ... because these are just good photos. ...the close up is handy, because that gives information about the stiffness"*

3D photo

The 3D photos seemed to be judged positively for mechanical properties. The technique had the highest average scores for thickness, weight, creasability, and glossiness. It performs less strongly on lightness, softness, and smoothness. Conveyance of mechanical properties may have been aided by depth cues from the fabric's overall volume and folds.

Participant feedback suggests that the depth effect helped make folds and protrusions more visible, which supported judgments of properties such as thickness. Several participants described the images as more lively or easier to interpret than standard 2D photographs, although others questioned whether the stereoscopic viewing was truly necessary and would have preferred more direct control, like the ability to rotate the object. Some participants reported some difficulty getting a clear or comfortable view using the headset.

> *"You can see the structure well ... and how it folds, how thick it is"*
> *"I think I would rank [2D photos] the same. ...I would like it if you could rotate it"*

3D scan

The 3D scans were judged most positively for thickness, stiffness, creasability, transparency, smoothness, and fragility. This may suggest that the ability to rotate the model and inspect it from multiple angles helped participants interpret overall form, folds, and surface structure. On the other hand, the technique performed less well for elasticity, softness, and the colour-related properties, indicating that the scans were less convincing when judgments depended more on realistic material appearance rather than geometric form.

Notable is that glossiness and transparency were on average rated positively, even though the scanned models did not contain reflectivity or transparency data. Some highlights and variations in brightness were effectively "baked into" the scan and remained visible (though static) when the model was rotated, which may have led participants to interpret gloss through these artefacts. In a similar phenomenon, some participants appeared to judge thickness from looking at the edge of the model. Even though the models were effectively zero-thickness shells and too coarse to capture true fabric edge thickness, there was visible rounding of the model at the edges, as well as some edge highlighting.

Participant suggestions for improvement mainly concerned making the scans more visually realistic, particularly through more accurate and vivid colour rendering.

> *"[The scan should be] more realistic in colour and*
> *[You should be] able to look through it with the light"*

Light sweep

Light sweeps appeared relatively strong at transparency, thickness, stiffness, and colour lightness, but weaker at elasticity and colour shade. The light sweep produced mixed responses, often with the same presentation being judged positively for some properties and negatively for others. These strengths seemed to result from the changing light direction making folds, creases, and larger surface structures highly visible.

Participant comments suggested that this mixed pattern was largely caused by the dramatic effect of the directional lighting. While the moving light helped reveal texture and shape, it also tended to exaggerate folds and wrinkles compared to the real garment. In addition, the wide range of lighting angles made the appearance of the garment fluctuate, which left some participants uncertain about which view should be taken as the most accurate. The light sweep therefore seemed useful for revealing some structural and optical cues, but less successful as a stable overall representation of the garment.

> *"[With the light in front] it's much flatter, [with side light] you can see the depth a little more"*
> *"It almost becomes a little exaggerated over what it really is, for example with the creases"*

> *"There is a very big difference between the end and the middle, which is a little confusing"*

Interaction video
The interaction videos were generally judged positively and appeared able to convey a wide range of fabric properties. They were rated particularly positively for stiffness, creasability, and colour lightness, but relatively weakly for glossiness. Regarding glossiness, it is notable that its score was lower than the other techniques, which all included at least some alternate, more directional lighting forms.
Participant comments suggest that the strengths of this technique lay in showing how the fabric behaved under manipulation. That said, the results also indicate that the exact gesture shown strongly influenced interpretation. For example, several participants noted that the amount of force used in the stretch video affected how elastic or thin the fabric appeared. Others suggested additional handling gestures: that transparency would be easier to judge if the fabric were shown against backlighting, and that creasability could be communicated better if the fabric were visibly straightened again after deformation. Overall, the videos seemed to provide rich and varied cues, but their effectiveness depended on how the interactions were staged.

> *"You can see the creasing very well, because it makes a creasing movement"*
> *"It looks like [the video] can stretch it much more than I can"*

3.3.3 Additional observations

Properties
Some properties, including stiffness, creasability, and fragility, appeared to be conveyed relatively well across several techniques, whereas others produced less uniformly positive responses. Particularly, colour lightness and shade, softness, smoothness, and elasticity showed less consistent judgments. Some properties might be inherently more difficult to convey visually, or depend more strongly on the exact way the garment is staged, lit, or manipulated. Additionally, some participants indicated ambiguity about the property warmness of touching, even though its conveyance was often rated positively.

Garments
The results also indicated that the specific garment had a substantial influence on perceived effectiveness. Some garments appeared consistently more difficult to represent than others, regardless of technique. For example, the bright pink T-shirt was difficult to capture photographically and tended to receive lower ratings across multiple presentations. Also, dark garments appeared sensitive to exposure, which could change their perceived lightness and surface detail.

Technique variants
As mentioned in Section 3.2.3, some techniques included internal variants. In addition to the per-technique patterns described above, several more fine-grained observations emerged when comparing the internal variants within one technique (although these comparisons must be interpreted with caution, as they were based on only a small number of exploratory comparisons within an already limited sample). For the standard photos, sets with original brand photographs tended to perform worse than the self-made photographs. A possible explanation is that the brand images were more visually uniform and aesthetically polished, but provided less varied or complete information about the fabric. As for the 3D photo technique, the variant with lighting from one side appeared to perform somewhat better than the others, possibly because the directional lighting strengthened the perception of depth and folds, although it also made some colour judgments less strong. Similarly, within the 3D scan technique, the Render Preview mode, which contained more directed lighting, seemed to perform better than the Material Preview mode with even lighting. Together, these observations suggest that not just the presentation technique itself, but also the specific visual conditions within that technique, can influence how informative the presentation appears.

3.3.4 General insights

Across the exploratory tests, no single presentation technique appeared to perform best for all fabric properties. Instead, different techniques seemed to support different kinds of judgments. Standard photographs provided a dependable baseline, but didn't seem to excel compared to the other techniques

on most specific properties. It might be valuable to amend standard photographs with other presentations to enhance the conveyance of specific properties. The interaction videos were generally well received and appeared promising for properties related to deformation and handling. At the same time, this technique introduces implementation variables that can influence its effectiveness; for instance, the force and speed of the interactions and the gesture(s) used. 3D photos also performed well, although it remains uncertain whether this was entirely due to the 3D effect itself, or also on the underlying quality and informativeness of the images used. Strong photographic cues for folds, depth, and surface structure may already contribute substantially to the perception of three-dimensional form, whether or not the image is viewed stereoscopically.
Another insight, which emerged across several presentation techniques, concerned the role of lighting. In the standard photographs, 3D photos, and 3D scans, different lighting conditions seemed to influence how garment properties were conveyed. When multiple lighting conditions of the same garment were shown, participants responded ambivalently: some found the additional variation helpful because it revealed more of the fabric, while others found it confusing because it was unclear which appearance should be trusted. Some participants appeared to treat one image as more leading or believable than another. This suggested that varying the lighting could either enrich the presentation or introduce ambiguity, depending on how it was interpreted.

> *"Each one has its own advantages"*
> *"With this one the colour matches, but you don't see the texture, [with the other one] you see the texture"*
> *"You can compare the images so you can ... sketch a general picture in your head"*
> *"It could be that it differs so much that you don't know what to believe"*

Taken together, these findings suggest that both the presentation technique and the specific stimulus setup within that technique can play a role in how well fabric properties are conveyed. They also indicate that greater visual richness is not automatically better: in some cases, extra information helped participants, while in others it made the representation harder to interpret.

3.4 Implications for the quantitative study

The exploratory tests generated broad design insight, but did not provide controlled evidence about which presentation technique was most effective. This, combined with the small sample size, made it difficult to isolate which aspect of the presentation was responsible for the observed effects.

With this in mind, it might be useful to move away from comparing broad presentation techniques as complete packages, and instead to investigate a more focussed, controlled variable in a quantitative study. One such controllable variable was the **effect of the specific lighting conditions** under which the presentation media were presented. This emerged from multiple tested presentation techniques, and could theoretically be relevant for any visual presentation technique. Within the exploratory phase, both during prototype construction and in participant responses, lighting repeatedly emerged for multiple presentation techniques as a factor that strongly influenced the interpretability of the apparent texture, depth, colour, and realism of the garments. However, as this phase was intended to generate broad design insight rather than controlled evidence and used a small sample size, it could not determine whether the reported differences would also translate into measurable differences in perception accuracy. It did not allow firm conclusions about which lighting situations are effective, or whether showing the garment under more lighting situations is helpful.

Therefore, a more controlled quantitative study was designed. This study focussed on the effect of lighting variation in still imagery, comparing more consistent single-lighting presentations with presentations that showed the same garment under multiple lighting conditions. It examined whether showing garments under multiple lighting conditions improves judgments of fabric properties, or whether it mainly increases perceived informativeness without improving actual judgment quality. Chapter 4 describes the study in detail.

4 Evaluating the effect of varied versus consistent images

4.1 Introduction

An important insight from the exploratory phase was that lighting conditions appeared to substantially influence the perception of fabric properties. Garments were presented using photographs taken under multiple lighting conditions, because it was not yet clear which type of lighting would be most effective for communicating the different qualities of the fabrics. Observations suggested that more directional lighting tended to emphasise three-dimensional shapes and surface texture, while more diffuse light de-emphasised these but may provide a more natural or colour-accurate representation.

Clothing is typically presented online under one controlled lighting condition (see Section 2.2.1). Although such lighting may optimise visual clarity and aesthetic appeal, it may not reveal all fabric properties equally well, nor show how a garment appears across the range of environments in which it is eventually seen. That could mean that a single lighting condition may not be sufficient to convey all relevant fabric properties effectively. Showing the same garment under multiple lighting conditions may provide additional visual information, but it could also introduce ambiguity if the garment appears markedly different across images. In the exploratory phase, some participants reported that multiple lightings helped them form a richer mental image of the fabric, while others found the varying appearances confusing because it was unclear which image most closely represented the “true” appearance (Section 3.3.4). It therefore remained unclear whether multiple lighting conditions actually improved **perception accuracy**, or mainly increased the **perceived diagnosticity** of the presentation.

A quantitative study was therefore conducted to compare single-lighting presentation with multiple-lighting presentation in a more controlled way. The study focussed on two lighting types that appeared most relevant in the earlier work: **diffuse lighting**, which provides relatively even illumination and reduces shadows, and **focus lighting**, which creates stronger directional shadows and highlights.
The aim was not to only compare diffuse and focus lighting as isolated categories, but more broadly to examine whether presenting a garment under more than one lighting situation could improve fabric-property judgments. Diffuse and focus lighting were selected as a practical contrast since are visually clearly different. The central question was whether showing garments under both lighting conditions would improve the accuracy of fabric-property judgments, increase confidence in those judgments, or both compared with showing only one lighting condition (and whether different lighting conditions were more conducive to different properties).

The aforementioned perceived diagnosticity was appropriate for the exploratory phase, since it allowed participants to compare techniques and give feedback about what aspects of the presentations aided their judgments. In this phase, the focus shifted from participants’ opinions about the presentation to the accuracy of the judgments it produced. This shift was important because the project ultimately aims to reduce the mismatch between online impressions and the real garment. Perception accuracy was therefore measured more directly by comparing judgments based on the online presentation with judgments of the real fabric.
Confidence was included as a second measure, because a presentation may increase a viewer’s sense of certainty without improving the accuracy of the judgments themselves. This distinction is also relevant in relation to the broader literature on online product presentation. Prior work has often focussed on purchase intention, sales, or perceived informativeness, whereas research on actual perceptual accuracy appears more limited (Creusen et al., 2025; Wijntjes et al., 2019). Measuring both made it possible to distinguish how lighting condition affected accuracy and confidence separately, as well as to examine whether these two outcomes actually corresponded. This was important because a presentation that feels more informative or convincing is not necessarily one that leads to more accurate judgments of the real fabric. This made it relevant to not just test the effects of lighting on accuracy and confidence separately, but to also examine whether confidence could be treated as an indicator of perception accuracy.

The exploratory phase included a broad range of properties. Not all of these properties were equally relevant in this phase, so a more focussed selection was made. The property set used in this quantitative study was narrowed to qualities that had emerged as relevant in earlier phases, were plausibly influenced by lighting, could be assessed in a controlled visual study.

4.2 Research questions

The quantitative study examined whether showing garments under multiple lighting conditions improves judgments of selected fabric properties. The following research questions were investigated:

> **RQ1**: Does showing garments under multiple lighting conditions lead to higher perception accuracy of fabric properties?
>
> **RQ2**: Does showing garments under multiple diverse lighting conditions lead to higher confidence in judging fabric properties?
>
> **RQ3**: What is the relationship between confidence and perception accuracy in judgments of fabric properties?

The study focussed on seven properties whose perception was expected to be plausibly influenced by lighting and that had emerged as relevant or problematic in the exploratory phase: glossiness, transparency, thickness, smoothness, colour lightness, colour warmness, and colour saturation.

Based on the assumption that additional visual information supports more accurate and confident judgments, the following hypotheses were formulated:

> **H1**: Showing garments under multiple lighting conditions leads to higher perception accuracy than showing garments under a single lighting condition.
>
> **H2**: Showing garments under multiple lighting conditions leads to higher confidence in judgment than showing garments under a single lighting condition.
>
> **H3**: Higher confidence is associated with higher perception accuracy.

4.3 Study design

4.3.1 Study design

The study used a partially repeated-measures design. Each participant completed four trials and saw each garment once, while encountering multiple lighting conditions across the four trials. The three presentation conditions were **Diffuse**, **Focus**, and **Both**, where the Both condition allowed participants to switch between the Diffuse and Focus images of the same garment.

This structure was chosen to balance two goals. First, the design avoided showing the same garment repeatedly under different lighting conditions to the same participant, as this would have introduced strong learning and comparison effects. Second, participants needed to encounter more than one lighting condition so that their responses were not tied entirely to one presentation style. A fully between-subjects lighting design was also not preferred, because it would have made the results more vulnerable to individual differences in scale use and reduced direct comparability between lighting conditions. The study therefore was set up to measure participants' first judgements of garments under different presentation conditions, while still allowing the influence of lighting condition to be examined across the dataset.

4.3.2 Participants

Participants were recruited through Prolific. To be eligible, participants had to be at least 18 years old, currently reside in a European country, and report normal or corrected-to-normal vision as well as normal colour vision. Participation was voluntary and financially compensated in line with Prolific guidelines.
A total of 61 valid responses were collected and included in the analysis. Of these, 29 were women, 30 were men, and 2 were nonbinary. Ages ranged from 18 to 74 years, with a mean of 39 and a median of 36 years. A breakdown by country of residence is available in Appendix F.1.

4.3.3 Materials

Garments

A set of four garments were selected for the study (Figure 4.1). To minimise influence of visual features other than the fabric itself, all garments were plain T-shirt without patterns, graphics, or major construction differences. The four garments were selected to cover a range of values across the properties included in the study. Based on an initial judgment by the researcher, the set together covered relatively low, medium, and higher values for each of the selected properties.



***Figure 4.1**. Overview of all stimuli.*

Presentations

The garments were presented under three lighting conditions:

- **Diffuse**: relatively diffuse lighting condition with overhead fluorescent lighting.
- **Focus**: garment is illuminated by a warmer single directed light source.
- **Both**: both the Diffuse and Focus lighting conditions (for the same garment) are shown, allowing participants to switch between them.

The Both condition was included to test whether access to multiple lighting conditions would improve judgments of fabric properties compared to a single-lighting presentation. In this condition, switching between the two lighting versions was done using a toggle interface, so that the images remained in the same position on screen and could be compared directly.

The two lighting types differed both in directionality and colour temperature. The aim of the study was not to isolate the effect of light directionality alone, but to compare more consistent versus more varied presentations. Differing the colour temperatures therefore helped to make the two lighting conditions visibly distinct.

Each garment was presented with two images (Figure 4.1): one frontal mannequin view and one draped over a stool. The mannequin view is provided a familiar presentation of the garment, giving a clear reference for shape and proportions. The drape view was added to provide more spatial folding and draping information. This choice was informed by earlier findings that three-dimensional fabric cues can support more accurate fabric judgments than flatter presentations (Xiao et al., 2016). Participants could zoom to 300% and pan by hovering the mouse over the image.

All images were taken on a Canon EOS100D DSLR camera. Full details of the capture setup and image production are provided in Appendix D.

4.3.4 Measures

Property ratings

The broad property set used in the exploratory phase was reduced for the quantitative study. Properties were selected based on their relevance in earlier phases of the project and their plausibility of their perception being influenced by lighting. The reduction also helped keep participant burden and study duration manageable.

Seven properties were measured (see also Section 2.1):

- Glossiness — How matte or shiny the fabric surface appears
- Transparency — How see-through the fabric appears
- Thickness — How thin or thick one layer of the fabric appears
- Smoothness — How even or irregular the fabric surface appears
- Colour lightness — How dark or light the colour of the fabric appears
- Colour warmness — How cool or warm the colour shade of the fabric appears
- Colour saturation — How muted or vivid the colour of the fabric appears

Colour warmness was used as a substitute for colour shade or hue. Although hue is an important aspect of colour, it is not well suited to the one-dimensional rating format used in this study. Hue is circular rather than linear, so translating it into a linear 0-100 scale could distort differences: for example, two colours that are close together on a circular spectrum could appear far apart numerically if they fall near opposite ends of the linear scale. A hue-based response format would also have turned the task more into a reference-based colour-matching exercise, whereas the other properties were judged on subjective scales without external calibration points. Colour warmness provided a clearer linear dimension that fit the study format and captured the kinds of lighting-related colour shifts that were expected, such as garments appearing somewhat warmer under one lighting condition and cooler under another, rather than shifting towards a completely different hue.

Colour saturation was included to capture a third aspect of colour appearance. Whereas colour lightness reflects how light or dark a colour appears and colour warmness reflects its position on a warm-cool dimension, colour saturation reflects how vivid or muted that colour appears. Including saturation therefore allowed colour perception and conveyance to be assessed more completely.

Properties were rated on a 100-point continuous scale, with markings at every 20 points. The markings provided subjects with a visual reference to precisely place their dots, while the 100-point scale allowed for distinguishing small average differences in perception. Each scale was labelled with a property name,

and each pole was separately labelled. Different words were used for both ends of a scale to minimise ambiguity (e.g. light-dark or light-heavy are clearer than light-not light).

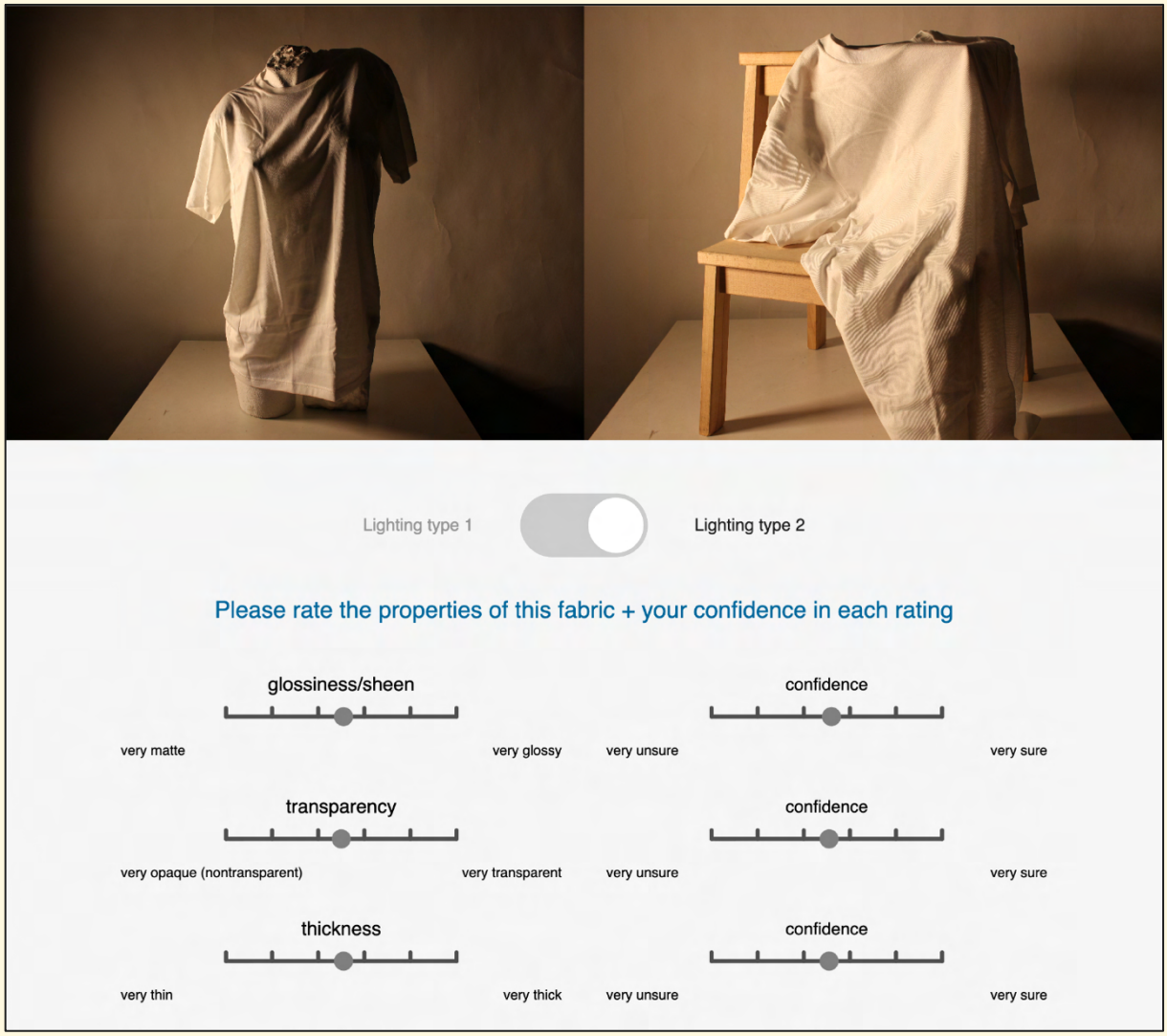


***Figure 4.2**. Experiment interface as presented to participants (truncated). A working example can be found at https://editor.p5js.org/dfn.cheng/full/Nuk5-Zy__*

Baseline ratings
Baseline values were established as the mean property ratings from an in-person test with the physical t-shirts (N = 30). See Appendix E; Table E.1.

Accuracy calculation
Perception accuracy was calculated by comparing each online property rating with the corresponding average baseline rating from the in-person fabric assessment:

$$Accuracy = 100 - |(property_{online} - property_{real})|$$

A score of 100 therefore indicates perfect agreement with the baseline rating, with lower scores indicating greater deviation.
For analysis of overall accuracy, a mean accuracy score was calculated across the seven properties for each observation.

Confidence
Next to every property, the subjects' confidence in their rating of that property was measured on a separate 100-point scale.
For analyses of overall confidence, a mean confidence score was calculated across the seven properties for each observation.

4.3.5 Procedure
Participants first completed a brief demographic questionnaire covering age, gender, education, employment status, country of residence.
Next, participants received instructions for the main task. Each property was briefly explained and the rating scales and interaction features (zooming, switching views, and changing answers) were explained. Subjects' perceptions were briefly calibrated by showing an overview of all possible stimuli together. This was done to allow participants to familiarise themselves with the range of fabrics they would be seeing, thus avoiding anchoring effects from the first garment viewed. These explanation pages are presented in Appendix F.1. After confirming that they understood the task, participants were led to the main experiment page.

In each trial, participants were shown two photographs of the same garment. In the Both condition, the two lighting versions of the garment could be compared using a toggle interface. Participants in this condition were required to switch at least once, to ensure that both lighting situations were viewed before making their judgments. Below the images, participants rated seven properties and their confidence in each judgment on continuous linear scales. The order of stimuli (both the garment and the light condition) was randomised, within the following constraints:

- Each participant sees a different garment in each trial
- Each participant sees all three light conditions at least once
- For the "BOTH" condition, the initial toggle state shown was also randomised

Each participant completed four trials, seeing each garment once. The median completion time was 8 minutes.

4.3.6 Data processing
Data quality was checked before analysis by verifying that both the demographic questionnaire and the main test had been completed. Responses were also screened for indications of inattentive or insufficiently serious participation. First, completion time was inspected at the trial level, with very short trials flagged for manual review. Second, ratings of colour lightness for the white and black garments were inspected as a basic plausibility check, since these garments should clearly differ in perceived lightness. Flagged cases were reviewed in the context of the participant's broader response pattern rather than being excluded automatically.
No clearly erroneous or invalid response patterns were identified. All data were retained for analysis.

4.4 Results
This Section presents the results from the online quantitative study. First, descriptive statistics are presented to provide an overview of the data. Subsequent Sections will present inferential analyses for each of the three research questions posed in Section 3.2. Statistical significance was evaluated at an alpha level of .05.

4.4.1 Descriptive statistics
Figures 4.3 and 4.4 below show the mean accuracy and confidence values per lighting condition. Both the values per property and an overall mean value are given. These values are aggregated over the four garments and all trials. The values used for these graphs can be found in Appendix F.2.1.

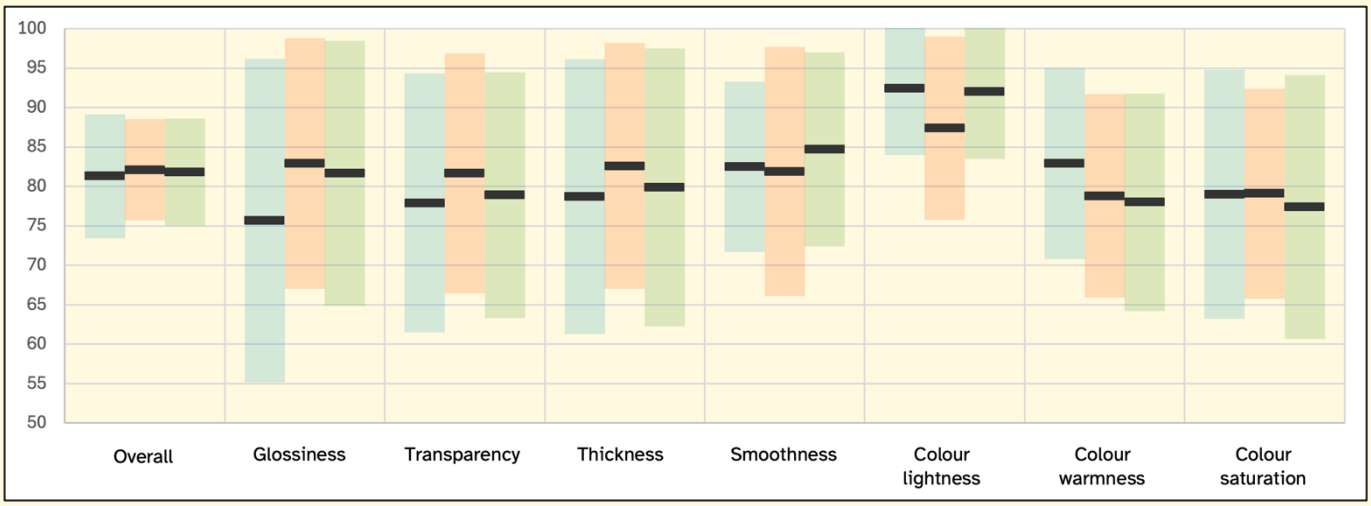


***Figure 4.3**. Mean perception accuracy per property and lighting condition, based on the full dataset. Black dashes indicate the mean accuracy score, and coloured bars indicate ±1 standard deviation. Within each property, the three conditions are shown from left to right as Diffuse (blue), Focus (orange), and Both (green).*

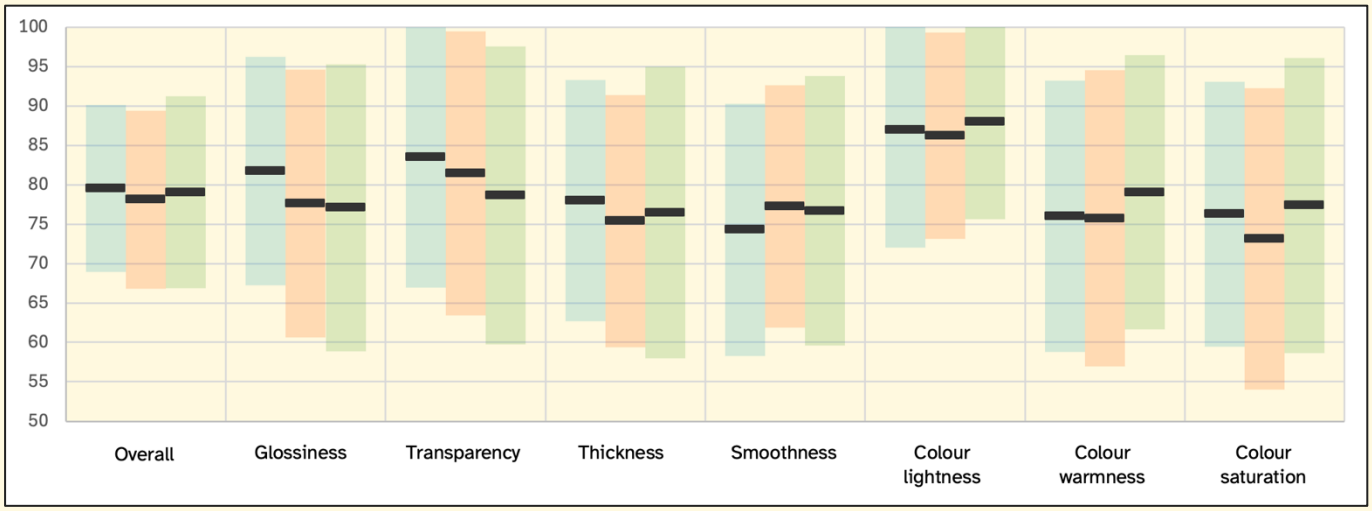


***Figure 4.4**. Mean confidence per property and lighting condition, based on the full dataset. Black dashes indicate the mean confidence rating, and coloured bars indicate ±1 standard deviation. Within each property, the three conditions are shown from left to right as Diffuse (blue), Focus (orange), and Both (green).*

Standard deviations were generally roughly 15 for both accuracy and confidence, indicating a moderate spread in responses. Descriptively, the differences between lighting conditions seem relatively small for both accuracy and confidence. For perception accuracy, the “Focus” lighting tends to show slightly higher means, though not for all properties. For confidence, “Diffuse” lighting seems to give the highest confidence in judgment of the mechanical and optical properties, whereas for accuracy these properties were better conveyed under “Focus” lighting. In contrast, the “Both” lighting seems to give a higher confidence in judging colour specifically.

In the next Section, statistical analyses will be performed to verify whether these differences are significant.

4.4.2 Effects of lighting condition on accuracy (RQ1)

To examine RQ1, a one-way repeated measures ANOVA was conducted.
As this analysis assumes independent observations within conditions, a data reduction step was required. Each participant contributed four trials: one for each lighting condition (diffuse, focus, both), and one additional trial with a randomly assigned condition. As a result, one lighting condition was repeated per participant, violating the assumption of independence. To address this, the extra trial was removed from the data set for this analysis. This left a sample size of N = 61 for each lighting condition.

Overall accuracy
First, the influence on overall accuracy (mean of all properties) was analysed.

***Table 4.1**. Mean (M) and standard deviation (SD) of overall accuracy per lighting condition (based on reduced dataset).*

Lighting condition	M	SD	N
Overall accuracy Diffuse	80.97	8.27	61
Overall accuracy Focus	81.55	6.62	61
Overall accuracy Both	81.65	6.80	61

Mauchly's test indicated that the sphericity could be assumed, $\chi^2(2) = 1.764$, $p = .414$. The repeated measures ANOVA showed that there was no significant effect of the light condition on overall accuracy, $F(2, 120) = 0.180$, $p = .836$, $\eta^2p = .003$.
This suggests that overall perception accuracy did not differ significantly between the lighting conditions.

Property-specific accuracy
For more granular secondary insights, a separate set of one-way repeated measures ANOVAs was run for the seven properties. Holm's sequential Bonferroni correction was applied across the seven p-values to control the family-wise error rate.

***Table 4.2**. Results of one-way repeated-measures ANOVA for each property (accuracy).*

	Mauchly's test	Uncorrected ANOVA result ($\alpha = 0.05$)	Holm corrected p ($\alpha = 0.05$)
Glossiness	$\chi^2(2) = 1.092$, $p = .579$	$F(2, 120) = 3.437$, $p = .035$, $\eta^2p = .054$	.212
Transparency	$\chi^2(2) = 0.196$, $p = .907$	$F(2, 120) = 0.552$, $p = .557$, $\eta^2p = .009$	1.000
Thickness	$\chi^2(2) = 1.502$, $p = .472$	$F(2, 120) = 0.509$, $p = .602$, $\eta^2p = .008$	1.000
Smoothness	$\chi^2(2) = 1.026$, $p = .599$	$F(2, 120) = 1.173$, $p = .313$, $\eta^2p = .019$	1.000
Lightness	$\chi^2(2) = 5.091$, $p = .078$	$F(2, 120) = 6.322$, $p = .002$, $\eta^2p = .095$	.014
Warmness	$\chi^2(2) = 1.716$, $p = .424$	$F(2, 120) = 2.285$, $p = .106$, $\eta^2p = .037$	.530
Saturation	$\chi^2(2) = 3.655$, $p = .161$	$F(2, 120) = 1.054$, $p = .352$, $\eta^2p = .017$	1.000

Before correction, significant effects of lighting condition were observed for Glossiness ($p = .035$) and Lightness ($p = .002$). However, after applying the Holm correction, only Lightness remains significant ($p = .014$).

This result indicates that only for the property *colour lightness* does the lighting condition affect the perception accuracy, while no significant effects were found for the other properties.

Pairwise comparisons showed accuracy for colour lightness was significantly higher in the Diffuse condition (M = 92.55) compared to the Focus condition (M = 87.43), p = .012. Similarly, the Both condition (M = 92.20) differed significantly from the Focus condition, p = .024, while no significant difference was found between the Diffuse and Both conditions.

4.4.3 Effects of lighting condition on confidence (RQ2)

Similarly to RQ1, a one-way repeated measures ANOVA was conducted for RQ2. The reduced dataset described in Section 3.4.2 was also used for this analysis to ensure one observation per lighting condition per participant.

Overall confidence

First, the influence on overall confidence (mean of all properties) was analysed.

Table 4.3. *Mean (M) and standard deviation (SD) of overall confidence per lighting condition (based on reduced dataset).*

Lighting condition	M	SD	N
Overall confidence Diffuse	79.47	10.45	61
Overall confidence Focus	78.31	11.37	61
Overall confidence Both	78.79	12.60	61

Mauchly's test indicated that the sphericity could be assumed, $\chi^2(2) = 1.626$, p = .443. The repeated measures ANOVA showed that there was no significant effect of the light condition on overall confidence, $F(2, 120) = 0.536$, p = .587, η^2p = .009.

This indicates that overall confidence did not differ significantly between lighting conditions.

Property-specific confidence

To obtain more detailed secondary insights, a separate set of one-way repeated measures ANOVAs was run for the seven properties. Holm's sequential Bonferroni correction was applied across the seven p-values to control the family-wise error rate.

Table 4.4. *Results of one-way repeated-measures ANOVA for each property (confidence).*

	Mauchly's test	Uncorrected ANOVA result (α = 0.05)	Holm corrected p (α = 0.05)
Glossiness	$\chi^2(2) = 5.331$, p = .070	$F(2, 120) = 3.920$, p = .022, η^2p = .061	.154
Transparency	$\chi^2(2) = 3.383$, p = .184	$F(2, 120) = 1.491$, p = .229, η^2p = .024	.740
Thickness	$\chi^2(2) = 2.893$, p = .235	$F(2, 120) = 1.713$, p = .185, η^2p = .028	.740
Smoothness	$\chi^2(2) = 1.111$, p = .574	$F(2, 120) = 0.513$, p = .600, η^2p = .008	.740
Lightness	$\chi^2(2) = 15.193$, p = .0005 Huynh-Feldt correction	$F(1.669, 100.148) = 1.218$, p = .295, η^2p = .020	.740
Warmness	$\chi^2(2) = 3.851$, p = .146	$F(2, 120) = 2.030$, p = .136, η^2p = .033	.680
Saturation	$\chi^2(2) = 0.330$, p = .848	$F(2, 120) = 2.934$, p = .057, η^2p = .047	.342

Before correction, significant effects of lighting condition were observed for Glossiness (p = .022). However, after applying the Holm correction, this effect was no longer statistically significant.
This result indicates that the lighting condition does not significantly affect confidence for any of the individual properties.

Overall, these results indicate that varying lighting conditions did not influence participants' confidence when judging the fabric properties.

4.4.4 Relation between confidence and accuracy (RQ3)

To examine RQ3, a linear mixed model (LMM) was conducted. For this analysis, the full dataset was used. Confidence was included as a fixed effect predictor of perception accuracy. Participant was included as a random intercept to account for repeated observations. Garment and lighting condition were included as additional fixed effects. Figure 4.5 provides a descriptive visualization of the relation between overall confidence and overall accuracy across all trials.

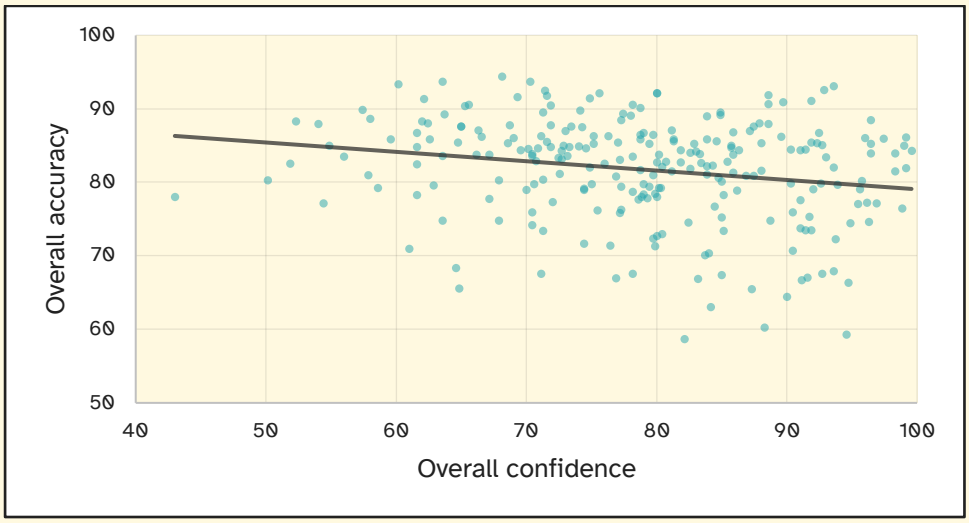


***Figure 4.5**. Descriptive relation between overall confidence and overall accuracy across all trials. The fitted line shows a slight negative trend. Inferential testing of this relation was conducted using a linear mixed model.*

Overall relationship
First, the relation between overall confidence and overall accuracy was investigated.

Overall confidence was found to be significantly associated with overall accuracy, b = -0.139, SE = 0.042, t(118.21) = -3.31, p = .001.
Overall accuracy differed by garment (F(3, 177.858) = 17.709, p < .001), while lighting condition was not significant in this model (F(2, 188.856) = .055, p = .947).

Sensitivity checks showed that the negative association between overall confidence and overall accuracy remained significant and similar in size both when garment and lighting condition were removed from the model as fixed effects and when a Garment × Lighting interaction was added, suggesting that the main confidence–accuracy finding was robust across these model variants.

These results suggest that participants who were more confident were not necessarily more accurate; in fact, higher confidence was associated with lower accuracy. Accuracy also differed between garments, but not between lighting conditions in this model.

Property-specific relationships

To further examine this relationship, separate linear mixed models were run for each property.

Results showed that the relationship between confidence and accuracy varied across properties. For six of the seven properties, confidence showed a negative association with accuracy, while colour lightness showed a nonsignificant positive association. After applying the Holm correction, the relationship remained statistically significant for transparency, colour warmness, and colour saturation.

***Table 4.5**. Results of linear mixed models for the effect of property-specific confidence on accuracy.*

Property	b	SE	df	t	p	Holm corrected p (α = 0.05)	F (light) p	F (garment) p
Glossiness	-0.095	0.066	179.824	-1.457	.147	.441	4.073 .018	15.022 .001
Transparency	-0.213	0.051	177.896	-4.209	.001	.007	1.187 .307	36.043 .001
Thickness	-0.080	0.062	139.141	-1.273	.205	.441	1.239 .292	15.098 .001
Smoothness	-0.109	0.054	159.239	-2.006	.047	.188	0.900 .408	2.292 .080
Lightness	0.050	0.048	196.044	1.040	.300	.441	8.407 .001	11.517 .001
Warmness	-0.126	0.046	151.512	-2.709	.008	.038	2.825 .062	2.006 .062
Saturation	-0.413	0.050	222.257	-8.305	.001	.007	0.947 .390	6.116 .001

Across properties, garment showed mostly significant effects, whereas the effect lighting condition was less consistent (see Table 3.8).

These results suggest that, both overall and for several individual properties, higher confidence was associated with lower perception accuracy, although this relationship is not consistent across all properties.

4.4.5 Exploratory follow-up analyses

In addition to the main analyses addressing RQ1-RQ3, several exploratory follow-up analyses were conducted to support interpretation of the results and to provide further insight into possible response patterns and interpretation tendencies. The first examined whether particular lighting conditions tended to produce overestimation or underestimation of specific fabric properties. The second and third focussed on how participants may have used the Both condition: one examined whether judgments in the Both condition tended to align more closely with Diffuse or Focus, while the other examined whether such alignment tended to follow the more accurate of the two single-light conditions. The fourth analysis examined whether trial time was associated with confidence and accuracy. Because these analyses were exploratory and not tied to additional formal hypotheses, they are interpreted tentatively.

Directional bias in property judgments

Signed error scores were examined to assess whether particular lighting conditions tended to produce systematic overestimation or underestimation of specific fabric properties. As the aim was only to identify possible directional patterns rather than to test a formal hypothesis, the results are presented descriptively (Figure 4.6). These values with sample sizes and standard deviations are available in Table F.3 (Appendix F.2.2).

Property	Diffuse	Focus	Both
Glossiness	-16.6	-3.9	-9.7
Transparency	-15.1	-12.6	-13.5
Thickness	12.1	7.1	12.0
Smoothness	0.4	-2.9	-2.5
Colour lightness	-0.6	-5.5	-0.1
Colour warmness	3.6	8.8	8.8
Colour saturation	-3.4	-5.4	-4.7

***Figure 4.6**. Mean signed error per property and lighting condition. Negative values indicate underestimation relative to the in-person baseline, and positive values indicate overestimation. Darker colours indicate greater absolute error.*

Several directional tendencies emerged. Glossiness and transparency were underestimated across all three lighting conditions, whereas thickness and colour warmness were generally overestimated. For some properties, the bias appeared to differ by lighting condition: colour lightness was close to unbiased in the Diffuse and Both conditions but somewhat underestimated in the Focus condition. Colour warmness was overestimated most strongly in the Focus and Both conditions. Glossiness also appeared to be substantially more underestimated in the Diffuse condition. These patterns suggest that lighting may influence not only how accurately a property is judged, but also the direction in which judgments are biased. Standard deviations (Appendix F.2.4) were relatively large at approximately 20-28 points, indicating substantial variability in the direction and magnitude of individual errors. Colour lightness showed somewhat lower standard deviations, indicating more consistent judgments for that property.

Tendency towards Diffuse or Focus in the Both condition

To examine whether the judgments in the Both condition were more similar to those in the Diffuse or in the Focus condition, the absolute distances were calculated between the mean Both rating and the mean Diffuse and Focus ratings for all 28 garment × property combinations. These values can be found in Table F.4 (Appendix F.2.2).

Descriptively, the Both condition was closer to Diffuse in 16 of 28 cases, and closer to Focus in 12 of 28 cases. The mean absolute distance to Diffuse (M = 4.85, SD = 4.51) was slightly smaller than the mean absolute distance to Focus (M = 5.85, SD = 4.02). However, a Wilcoxon signed-rank test showed that this difference was not significant, Z = 1.07, p = .285. This seems to indicate that judgments in the Both condition were not systematically closer to either the Diffuse or the Focus condition.

A descriptive breakdown per property suggested that this absence of an overall alignment tendency may have masked some property-specific tendencies. For transparency, thickness, and smoothness, the Both condition was more often closer to the Focus condition (3 out of 4 garments), whereas for colour lightness and colour warmness it was more often closer to the Diffuse condition (4 out of 4 garments). Saturation showed no clear tendency; suggesting that, when both lighting conditions were available, judgments may have been drawn towards the lighting view that best supported the property being judged rather than consistently towards one lighting type overall. These property-level patterns are purely descriptive and should be interpreted with caution, as each property comparison is based on only four garment-level mean values, and no inferential analyses are conducted at the property level.

Alignment of the Both condition with the more accurate single-light condition

The exploratory analysis above concluded that there was no *overall* alignment tendency towards one of the conditions, but that there might be some property-specific tendencies. The results for RQ1 showed that the Diffuse and Focus lightings did not differ significantly in accuracy, except for the colour lightness property (Section 4.4.2). It may still be informative to examine, at the level of individual garment × property combinations, whether judgments in the Both condition tended to align more closely with whichever of the two single-lighting conditions happened to be more accurate in that specific case. For each garment-property combination, it was determined whether Diffuse or Focus had the higher mean accuracy, and to what extent the mean rating in the Both condition was closer to that condition or the less accurate one. An overview of this can be found in Table F.5 (Appendix F.2.2).

A Wilcoxon signed-rank test showed that the Both condition was significantly closer to the more accurate single-light condition than to the less accurate one, Z = 2.00, p = .045. Descriptively, the Both judgment was closer to the more accurate single-light condition in 19 of the 28 combinations. This gives some indication that, when both lightings were available, judgments tended to be pulled more strongly towards the relatively more accurate single-light view. This pattern was especially clear for colour lightness, for which the Both judgment aligned with the more accurate Diffuse light condition in all four garment cases.

Because this was an exploratory follow-up analysis based on a limited number of garment × property combinations, the finding should be interpreted with caution. It should also be considered in light of the broader RQ1 result, which showed no statistically significant accuracy difference between Diffuse and Focus except for colour lightness.

Relation between trial time, accuracy, and confidence

Finally, the relation between trial time and both overall accuracy and overall confidence was examined to explore whether longer response times reflected more careful inspection or greater difficulty in judgment. Two linear mixed models were conducted, using the full dataset. Trial time (in seconds) was included as a fixed effect predictor of perception accuracy and of confidence. Participant was included as a random intercept to account for repeated observations. Holm correction was applied across the two models.

Trial time was not found to be significantly associated with overall confidence, b = -0.010, SE = 0.010, t(201.73) = -0.99, p = .326 (corrected).

Trial time was found to be significantly negatively associated with overall accuracy, b = -0.023, SE = 0.009, t(227.96) = -2.72, p = .014 (corrected).

The results suggest that spending more time on a trial was not related to confidence, but was associated with slightly lower accuracy. The effect size was small: an increase of 10 seconds in response time would correspond to an approximate decrease of 0.23 points in accuracy.

4.5 Discussion

This Section interprets the results of the quantitative study and their implications for online fabric presentation design.

Besides the differences between lighting conditions the accuracy levels themselves are also informative. Mean accuracy values were generally around 80 out of 100, indicating that participants were often able to form a roughly appropriate impression of the fabrics from the online presentations, but that noticeable deviations from the in-person mean baseline remained. That suggests that the challenge was not one of complete misperception, but more of improving an already moderately accurate impression. The accuracy scores were calculated relative to a mean in-person baseline rating, rather than to an objective physical ground truth. For properties or garments with greater variability in the baseline judgments, the reference values were less stable, which may have influenced the magnitude of the resulting accuracy scores. The relatively high baseline accuracy may also have limited the room for lighting manipulations to produce large additional gains.
Confidence levels were also generally high, with mean values roughly hovering around 75-85 out of 100. Similarly to accuracy, this indicates that participants were generally reasonably sure about their judgments. It seems that the presentations were generally interpretable and provided enough visual information for participants to form a confident impression of the fabrics. Nevertheless, the confidence scores were not at the very top of the scale, indicating that participants still experienced some uncertainty and that there is also room for improvement in confidence.

4.5.1 Effects of lighting condition on accuracy (RQ1)

The results indicate that presenting fabrics under multiple lighting conditions did not lead to a general improvement in perception accuracy. No significant effect of lighting condition was found for overall accuracy, and no significant differences were observed for most individual properties.
This finding helps to qualify impressions from the exploratory phase (Chapter 3), in which varied lighting sometimes seemed ambiguously helpful because it appeared to reveal additional information, but it remained unclear whether this additional information also improved actual understanding of the fabric and perception accuracy.

An effect was only observed for the property **colour lightness**, for which lighting condition significantly influenced perception accuracy. Pairwise comparisons showed that the Diffuse and Both conditions scored better than Focus, but Diffuse and Both did not differ significantly from each other. This suggests that colour lightness is better conveyed under the Diffuse lighting condition and that providing an additional lighting view does not improve accuracy beyond the better-performing single-light condition.

One possible explanation for the lack of a clear advantage of the Both condition is that participants may not have integrated the two lighting views into a single, more accurate judgment. Instead, they may have relied more strongly on whichever view appeared most informative or plausible for the property they were judging. In that case, the additional view would not necessarily improve accuracy, but would mainly allow participants to anchor their judgment to the more useful of the two representations. This interpretation is consistent with the exploratory phase, in which some participants appeared to treat one of multiple views as more leading than the other, and with the follow-up analyses (discussed in Section 4.5.4) suggesting that judgments in the Both condition tended to align more closely with the relatively more accurate of the two single-light conditions. Multiple lighting conditions also introduce variation in appearance without making clear which representation most closely reflects the real fabric. The additional information may therefore increase the number of available cues without increasing their usefulness or interpretability.

This does not explain, however, why the Diffuse and Focus views were not significantly different in most cases. That pattern seems to suggest that, with the present setup, the two single-light presentations often provided sufficient information for similarly accurate judgments. Although the lighting conditions visibly differed, participants may have been able to partly compensate for these differences and infer the underlying fabric properties similarly across conditions. In other words, some viewers may have

mentally compensated for the lighting context by treating part of the appearance difference as an effect of the lighting rather than of the fabric itself, and adjusted their property ratings accordingly. If such compensation occurred, it would help to explain why the mean accuracies of Diffuse and Focus were relatively close for most properties.
In addition, any small property-specific advantages of one lighting condition over the other may have averaged out in the overall analyses or remained too small relative to participant or garment variability to emerge as statistically reliable effects.

The specific effect for colour lightness may be explained by the more direct dependence of perceived lightness on illumination. Diffuse lighting provided a more even and neutral representation, whereas the Focus condition made the garment appear darker overall and introduced a warmer colour cast. This may have made it harder for participants to judge the actual lightness of the fabric, even when the background context remained visible. In this case, the appearance shift produced by the Focus setup may simply have been too strong to be fully offset with mental compensation.
A further possible contributing factor is that the Diffuse images were captured in the same room, under similar lighting, as the setting used for the in-person baseline ratings. For colour lightness in particular, this may have made the Diffuse condition visually similar to the baseline reference, which could have contributed to its higher accuracy. However, this explanation is likely to apply less strongly to other properties, since the baseline assessment involved free handling of the fabrics which gave access to cues not available in Diffuse. For example, in-person participants could hold the fabric up against the light to inspect transparency, so the similarity between Diffuse and baseline was not complete.
It is also notable that colour lightness showed relatively lower variability in both the in-person baseline judgments and the online ratings compared with most other properties. This suggests that colour lightness may have been a more consistently judged property overall, making differences between lighting conditions easier to detect statistically.

Although most property-specific effects were not significant after correction, the descriptive pattern suggests that different lighting conditions may emphasise different visual cues. Glossiness, for example, tended to be conveyed more accurately under Focus lighting, while colour lightness was conveyed more accurately under Diffuse lighting. These trends were small and did not translate into statistically reliable property-specific effects, except for colour lightness. They can therefore only be treated as tentative trends rather than evidence of property-specific superiority of one lighting condition, but they do suggest that more directional lighting may strengthen cues related to reflectivity, shape, and structure, while more diffuse lighting could support a more stable reading of colour-related properties.

From a design perspective, this implies that simply adding more lighting conditions is not sufficient to improve perception accuracy. However, when different properties are better supported by different lighting setups, there may still be value in presenting fabrics under multiple complementary lighting conditions, not because this improves overall accuracy directly, but because it may support the perception of different aspects of the material. Such added views may however need clearer framing or explanation if they are to become more informative rather than merely more varied.

4.5.2 Effects of lighting condition on confidence (RQ2)

The results indicate that presenting fabrics under multiple lighting conditions did not increase participants' confidence in their judgments. No significant effect of lighting condition was found for overall confidence, and no significant effects were found for any of the individual properties. Showing both lighting conditions did not make participants feel more certain about their judgments than showing only one lighting condition, nor was one lighting condition better than the other in terms of confidence.

This finding is consistent with the mixed pattern already observed in the exploratory phase (Section 3.3.4). In those earlier tests, some participants experienced multiple views as helpful because they seemed to provide more complete information, while others found them confusing because the garment appeared different across images. The quantitative results indicate that these opposing impressions did not translate into a consistent overall effect on confidence in either direction.

One possible explanation is that additional visual information does not automatically lead to greater certainty. Showing the same garment under two lighting conditions may provide more visual cues, but it also introduces more variation in appearance. Without a clear indication of how the two views should be interpreted, participants may not have experienced the additional information as easier to integrate into a stable judgment. For some viewers, the second view may have increased confidence by providing more cues, whereas for others it may have reduced confidence by introducing ambiguity. At the group level, those opposite effects may have cancelled each other out. So, the Both condition may have increased the amount of available information without increasing its interpretability. Rather than being better than the sum of its parts, the Both condition appears to have combined potentially helpful and potentially confusing cues, resulting in no clear confidence benefit.

A similar averaging-out effect may have also occurred between the Diffuse and Focus conditions. Although these conditions did not involve the challenge of integrating two views, different participants may still have found different lighting situations more confidence-inspiring. Some viewers may have preferred the stronger structural cues in the Focus condition, whereas others may have felt more certain under the more even and natural-looking Diffuse lighting. Such opposing tendencies could also contribute to the small mean differences between the single-light conditions.

It is also possible that participants mentally compensated for the lighting situation. Because the scene context was visible and illuminated in the same way as the garment, viewers may have felt able to interpret some of the garments' appearance as an effect of the lighting rather than of the fabric itself. If so, they may still have been able to form a reasonably confident impression of the fabrics regardless of the lighting condition they were shown under. This internal compensation could also explain the small difference in the means of the three lighting conditions.

From a design perspective, these findings suggest that simply adding another lighting view is not enough to increase users' certainty.
If multiple lighting conditions are to support confidence, the presentation may need to guide viewers more explicitly in how the different appearances should be interpreted, for example by indicating what each lighting situation is intended to reveal and represent. Such guidance may not be necessary because viewers are completely unable to interpret multiple lighting conditions, but because clearer explanation could make that interpretation more consistent and less ambiguous across users. Without it, additional views may remain helpful and informative for some viewers, while introducing uncertainty for others.

4.5.3 Relation between confidence and accuracy (RQ3)

For overall judgments, and for several individual properties, higher confidence was associated with lower perception accuracy. This was opposite to the hypothesis that greater confidence would reflect more accurate judgments. Although the observed relationships were generally small, they suggest that feeling certain about a judgment did not necessarily mean that the judgment was more correct. Instead, the results point towards a possible mismatch between subjective certainty and actual perceptual accuracy.

One possible explanation is that some presentations may have appeared clear, convincing, or easy to interpret without actually supporting more accurate judgments. In an online setting, viewers lack touch and must rely primarily on visual cues, which may create a seemingly diagnostic but incomplete impression of the fabric. Confidence may then reflect how coherent or interpretable a presentation appears, rather than how well it matches the real fabric. In that sense, participants may sometimes have felt certain for the wrong reasons.
Lower confidence may also indicate that viewers recognised the ambiguity of the task and were cautious with their judgments. They may in some cases have given less extreme property ratings, thereby reducing large deviations from the baseline reference.
In addition, since accuracy was defined as agreement with a mean human baseline, confident but idiosyncratic judgments can also score as inaccurate.

This study cannot determine which of those mechanisms was responsible. It does, however, show that confidence should not automatically be treated as a proxy for perceptual accuracy in online fabric presentation.

For the overall model, lighting condition did not show a significant effect, suggesting that this negative confidence-accuracy relation was not limited to one specific lighting condition. This is also consistent with the results of RQ2, which showed no overall effect of lighting condition on confidence. The pattern therefore seems to reflect a broader feature of the judgment process rather than a confidence bias tied to one particular presentation format.

From a design perspective, these results suggest that increasing users' certainty is not necessarily the same as improving their expectations. A presentation may make viewers feel more certain without making them more accurate. For online fashion presentation, this implies that the goal should not simply be to maximise confidence, but to support judgment that are well calibrated to the real properties of the fabric. In that sense, some degree of uncertainty may therefore be preferable to misplaced certainty, although this study did not measure downstream outcomes like satisfaction after receiving the garment.

The findings also have a broader implication for research and practice in online product presentation. If higher confidence does not necessarily reflect higher accuracy, then increasing users' sense of certainty should not be treated as a sufficient design goal in itself when the aim is to convey a material effectively. This is especially relevant because prior work on online presentation has often focussed on increasing purchase intention, sales, or perceived informativeness, whereas research on actual perception accuracy appears more limited (Creusen et al., 2025). The present results therefore support an approach in which confidence and accuracy are assessed separately, so that presentations can be evaluated both on how convincing they appear and on whether they help consumers form expectations that better match the real product. This distinction is consistent with earlier work showing that presentation features can increase confidence in evaluation without necessarily improving the underlying judgment in the intended way (Peck & Childers, 2003), and that presentations may appear informative or diagnostic without necessarily improving the match between product prediction and real product experience (Wijntjes et al., 2019). It is also reflected in the structure of this project: whereas the exploratory study in Chapter 3 focussed on participants' metacognitive impressions of how well presentations seemed to convey material properties, the study in Chapter 4 examined more directly whether the presentations supported accurate judgments of the real fabrics.

Two property-specific cautions should also be noted. First, the negative confidence-accuracy relation for transparency may partly reflect the fact that transparency was difficult to assess from the online stimuli. In the in-person baseline assessment, participants could inspect the fabric by holding it against the light, whereas this was not possible in the online presentation. As a result, transparency appears to have been generally underestimated across conditions (see Figure 4.6). The relative lack of strong transparency cues may have given viewers a general impression of opaqueness, which may have contributed to a mismatch between subjective confidence and actual accuracy for this property.

Second, saturation was one of the properties for which a significant negative relation was found, but this measure was also less meaningful for the black and white garments. For these garments, participants may have interpreted the scale in very different ways, leading to highly variable ratings in both the in-person baseline and the online study. If the resulting baseline mean fell around the middle of the scale, ratings at either end would appear strongly inaccurate, even when they reflected a consistent personal interpretation. This may have contributed to the negative confidence-accuracy relation found for saturation.

4.5.4 Exploratory follow-up analyses

Directional bias in property judgments

The exploratory signed-error analysis suggests that the different lighting conditions may not just influence how accurate property judgments are, but also the direction in which those judgments are biased.

Several properties showed fairly consistent directional tendencies across conditions. Transparency was generally underestimated, which may be explained by the fact that none of the presentations showed the fabric with strong light directed through the garment at the camera. Although the Focus setup did allow some light to pass through the fabric, this effect was subtle and may not have been sufficiently noticeable for viewers to judge transparency well. Thickness, by contrast, was overestimated across conditions. One possible explanation is that when transparency cues are weak, viewers may infer that the fabric is thicker than it is, although this remains speculative.
Some biases also appeared to vary by lighting condition. Glossiness was most strongly underestimated in the Diffuse condition, which is plausible given that diffuse lighting dulls highlights that could otherwise serve as cues for glossiness. The Focus images, by design, placed greater emphasis on directional highlights and may therefore have made any glossiness more visible. Colour lightness was relatively unbiased in the Diffuse and Both conditions, but was underestimated in the Focus condition. This may be because the Focus images appeared darker overall, making the garments themselves seem darker as well, even though the darker background could in principle have provided some contextual correction. Colour warmness showed the same pattern in the opposite direction: it was overestimated most strongly in the Focus and Both conditions, which is consistent with the warmer appearance of the Focus images in general. Together, these patterns suggest that lighting may accentuate or suppress particular visual cues, thereby shifting judgments in predictable directions rather than merely adding random noise.

These observations are relevant because two presentation conditions can show similar absolute accuracy while still producing different perceptual distortions. A lighting condition may therefore not improve judgments overall, yet still make garments appear darker, warmer, glossier, or thicker than they are perceived in person. Nonetheless, this analysis was exploratory and descriptive, so these directional patterns should be treated as tentative indications rather than definitive effects.

Tendency towards Diffuse or Focus in the Both condition
The exploratory alignment tendency analysis suggests that, when participants were shown both lighting conditions, their judgments did not simply default to either the Diffuse or the Focus view overall. Across all garment × property combinations, the Both condition was not significantly closer to one single-light condition than to the other. This indicates that participants were not consistently anchoring their judgments to one lighting type as a general default.
At the same time, the descriptive breakdown by property suggests that this absence of an overall effect may conceal more specific tendencies. For transparency, thickness, and smoothness, judgments in the Both condition were more often closer to the Focus condition, whereas for colour lightness and colour warmness they were more often closer to the Diffuse condition. Although these patterns are based on only four garment-level mean values per property and should therefore be interpreted cautiously, they suggest a plausible interpretation: when both lighting conditions are available, viewers may rely more strongly on the view that provides the most useful cues for the particular property they are judging, rather than consistently privileging one lighting condition overall. This interpretation also resonates with observations from the exploratory phase (Section 3.3.4), where some participants appeared to privilege one of multiple views over another, or expressed uncertainty about which image should be trusted.

If this interpretation is correct, it would imply that the value of showing multiple lighting conditions may not primarily lie in showing how a garment might appear in different environments, but in allowing viewers to draw on different visual cues for different kinds of judgments. This also helps contextualise the feedback from the exploratory phase, in which some participants reported uncertainty about which of multiple views they should “believe”. The present result suggests that viewers may not simply choose one view as the correct one, but may instead shift between views depending on the property they are trying to assess. However, because this analysis was exploratory and based on aggregated means, it remains uncertain to what extent these apparent tendencies reflect stable perceptual tendencies rather than noise in a small set of cases.

Alignment of the Both condition with the more accurate single-light condition
Although Diffuse and Focus did not differ significantly in overall accuracy in RQ1, this exploratory follow-up analysis suggested that judgments in the Both condition were nevertheless more strongly drawn toward the relatively more accurate of the two single-light conditions. This adds an important nuance to

the tendency analysis above: rather than defaulting overall to Diffuse or Focus, judgments in the Both condition appear to have been shaped more often by whichever single-light view was more informative for the specific property at hand.
Taken together, these findings suggest that the Both condition may not have introduced a fixed bias toward one lighting type, but may instead have supported a more selective use of the available visual information. This gives a more specific interpretation to the exploratory observations in Chapter 3: rather than simply choosing one image arbitrarily, participants may sometimes have been drawn more strongly to the view that provided the more useful cues for the property being judged.

This finding also should be interpreted cautiously. The analysis was exploratory, based on a limited number of garment × property combinations, and the broader RQ1 results did not show a general accuracy advantage of one light condition over the other, except for colour lightness. The study also did not track whether participants switched to specific views for specific properties. The result therefore does not show that viewers consciously chose the “best” view, but rather that the resulting judgments in the Both condition tended to resemble the relatively more accurate single-light condition more often than not. This may point to an adaptive use of multiple visual cues, but further research would be needed to determine how stable and general this tendency is.

Relation between trial time, accuracy, and confidence
Another exploratory analysis examined whether trial time was related to confidence and accuracy. Trial time was not significantly associated with confidence, suggesting that spending longer on a trial was not simply a matter of participants feeling less certain about their judgments. The small but significant negative relation between trial time and accuracy, however, indicates that longer inspection did not improve performance. Rather than reflecting careful and effective inspection, longer trial times may instead have marked trials that were harder to interpret. Participants may have spent extra time because the specific presentation was more ambiguous, because a property was harder to judge, or because they were second-guessing their initial impression. It is also possible that certain garments or lighting situations were intrinsically more difficult to interpret, leading to both longer trial times and lower accuracy. Since this was an exploratory analysis and did not examine the relation between trial time and specific garments or lighting conditions, these interpretations remain tentative.

Garment influence
Across the analyses, it appears likely that differences between garments contributed substantially to the observed variability. The four garments differed in their baseline property profiles and variability of their ratings, which may have reduced the relative visibility of lighting effects in the aggregated analyses. This interpretation is supported by the RQ3 models, in which garment showed significant effects on accuracy levels. The present results should therefore be interpreted in relation to the specific garments tested: any effect of lighting occurred within a context where some garments were inherently easier or harder to judge than others.

4.6 Limitations

This study has several limitations that should be considered when interpreting the results.

Baseline ratings
Perception accuracy in this study was calculated in relative to baseline ratings of the real garments. These baseline values were derived from the mean judgments of participants who evaluated the physical fabrics in person. As a result, the accuracy scores do not represent deviation from an objective physical ground truth, but from an aggregated human reference. This is appropriate for a project concerned with *perceived* fabric qualities, since consumer experience is itself subjective. It also means, though, that any variability in the baseline judgments is also carried into the calculated accuracy scores. For properties or garments with greater variability in the baseline ratings, the reference values were less stable, which may have affected the resulting accuracy scores. Full baseline results are reported in Appendix E.

Viewing conditions
The study was conducted online, which meant that participants viewed the stimuli on their own devices. Participants were asked to disable any colour filters on their displays, but viewing conditions including brightness, colour reproduction, screen resolution, and ambient lighting could not be fully controlled. These differences may have affected the perception of the garment images. While this made the study less controlled, it does reflect the real-world context of online shopping, in which consumers likewise view garments under uncontrolled everyday conditions.

Garment set
The stimulus set was limited to T-shirts only. This helped to reduce variation in garment construction and made it easier to focus on differences in fabric properties, but it also limits the generalisability of the findings. The selected garments covered a range of values on the measured properties, yet they do not represent the full diversity of textiles and garments found in online fashion retail. It is possible that larger or different effects would emerge for other fabrics or garment categories.

Study design
In order to avoid strong learning and comparison effects, it was not possible to show each participant all possible garment-lighting combinations. Each participant viewed a subset of four garment-lighting combinations, covering all four garments but repeating one lighting condition. As a result, the dataset did not form a perfectly balanced repeated-measures structure suitable for all analyses. For the ANOVAs addressing RQ1 and RQ2, a reduced dataset was used in which each participant contributed one observation per lighting condition. Although this made the analyses more appropriate, it also reduced the effective sample size and made the study design was less statistically efficient than a fully balanced within-subjects design would have been.

Lighting manipulation
The comparison between lighting conditions was not isolated to directionality alone. The Diffuse and Focus conditions also differed in colour temperature. This was a deliberate design choice, because the aim was to compare clearly distinct lighting situations rather than to isolate one technical lighting parameter. It also means, however, that the study cannot disentangle whether the observed effects were caused by the directionality, colour temperature, or both.

Presentation format
The study examined one specific still-image presentation format consisting of two views per garment and, in the Both condition, a toggle between two lighting states. The findings therefore inform this particular type of online presentation, but do not automatically generalise to other formats including video or 360-degree views.

Measures
The quantitative study focussed on a reduced subset of seven properties. This helped to keep the experiment manageable, but it also means that the findings do not cover all potentially relevant fabric qualities. Additionally, some properties may have been more visually or conceptually straightforward to judge than others. For example, colour lightness showed relatively low variability compared with several other properties, which may have made effects on lightness easier to detect statistically.

A further limitation concerns saturation specifically. This property was included alongside lightness and warmness to capture a more complete picture of colour appearance, but it was less applicable to the black and white garments in the stimulus set. Responses for saturation also showed large variability, suggesting that this property may have been judged less consistently than some of the other measures. Findings involving saturation, including those in RQ3, should therefore be interpreted with additional caution.

No behavioural outcome
The study measured perception accuracy and confidence, but not downstream outcomes like purchase decisions, satisfaction after receiving the item, or return behaviour. The findings therefore indicate how lighting conditions affected judgments, but do not directly demonstrate whether these presentation

differences would reduce returns in practice. In addition, the study does not establish what level of perception accuracy should be considered sufficient in practice. The amount of mismatch that is acceptable is likely to depend on the property, garment, and consumer context. As a result, even where differences in accuracy are observed, their practical significance for online retail outcomes remains uncertain.

Interpretation of RQ3
The analyses for RQ3 examined whether confidence and accuracy were associated, but they do not establish a causal relationship between the two. A negative or positive association does not show whether confidence influenced accuracy, accuracy influenced confidence, or both were shaped by other factors.

4.7 Conclusion

This Chapter examined whether showing garments under multiple lighting conditions improves judgments of fabric properties compared with showing only one lighting condition. It investigated whether multiple lighting conditions improve perception accuracy, increase confidence in judgment, and how confidence relates to accuracy.

The results showed that varied lighting did not provide a general advantage over consistent single-light presentation. For **RQ1**, no significant effect of lighting condition was found for overall perception accuracy. At the property level, only **colour lightness** was significantly affected by lighting condition: accuracy was higher in the **Diffuse** and **Both** conditions than in the **Focus** condition, while Diffuse and Both did not differ significantly from each other. This suggests that diffuse lighting supported more accurate judgments of colour lightness, but that showing both lighting conditions did not improve accuracy beyond the better-performing single-light view.

For **RQ2**, lighting condition did not significantly affect confidence. Showing both lighting conditions did not make participants feel more certain about their judgments than showing only one lighting condition, and no significant confidence differences were found for the individual properties after correction. This indicates that additional lighting variation did not consistently make the presentations feel more informative or easier to judge.

For **RQ3**, confidence and accuracy did not relate in the expected way. Instead, higher confidence was associated with lower perception accuracy overall, and this negative relation was also found for several individual properties. That result suggests that feeling certain about a judgment did not necessarily mean that the judgment was more correct. Confidence should therefore not be treated as a proxy for perceptual accuracy in online fabric presentation.

Taken together, these findings suggest that simply adding another lighting view is not sufficient to improve online fabric communication. Multiple lighting conditions did not improve overall accuracy or confidence, although the exploratory follow-up analyses suggest that when both views were available, judgments were sometimes drawn more strongly towards the relatively more accurate single-light representation for a given garment-property combination. The main implication is therefore not that more lighting conditions are always better, but that online fabric presentation should be evaluated by how well it supports accurate expectations of the real product rather than by how informative or convincing it seems.

5 Design synthesis & guidelines

This Chapter brings together the insights from the literature review, exploratory prototyping and testing, and the quantitative evaluation. Rather than presenting a single “best” presentation technique, the project aimed to understand which visual cues are important for judging fabric properties online, how different presentation choices support or hinder those judgments, and what this means for the design of online fabric presentation.

The previous Chapters showed that fabric-property perception is not supported equally by all visual cues, and that richer presentation is not automatically better. Some presentation choices appeared promising because they revealed additional information, but they could also introduce ambiguity or increase the difficulty of interpretation. This Chapter therefore synthesizes the findings into a set of design implications and guidelines for online fabric presentation, and translates these into a prototype direction.

5.1 Key findings to inform guidelines

Across the project, a central theme was that different fabric properties depend on different visual cues. Properties related more strongly to colour, such as colour lightness, were influenced by how evenly and neutrally the fabric was lit. Properties related more strongly to surface structure and reflectivity, including glossiness, appeared more dependent on directional highlights, shadowing, and visible three-dimensional form. This means that no single presentation setup is likely to be optimal for all fabric properties at once.

A second recurring finding was that adding more information does not automatically improve judgment. In the exploratory phase, multiple views with different lighting situations were sometimes experienced as helpful because they seemed to provide a richer impression of the fabric. At the same time, they could also make interpretation harder when the garment appeared too different across images. The quantitative study supported this tension: showing both lighting conditions did not produce a general increase in either perception accuracy or confidence. This suggests that richer presentation only becomes valuable when viewers can still interpret the available cues clearly.

A third important finding is that confidence and accuracy should not be treated as the same outcome. The quantitative study showed that higher confidence did not necessarily correspond to more accurate judgments, and in several cases was even associated with lower accuracy. This implies that presentations can feel clear, convincing, or informative without actually helping consumers form expectations that better match the real garment.

Together, these findings point towards a central design trade-off: online fabric presentation should offer enough visual richness to reveal relevant material cues, but not so much variation that the presentation becomes ambiguous or hard to interpret. The challenge is therefore not simply to add more views, more motion, or more lighting variation, but to present complementary information in a way that remains legible and meaningful to the viewer.

5.2 Product page mockup design

The guidelines are illustrated through a product-page mockup that translates the project findings into a realistic online fashion retail context. The mockup does not propose a radically new shopping interface, but shows how fabric-specific support could be incorporated into a familiar product-page structure. It combines a clear reference image with selected complementary views, including switchable lighting, a drape and close-up view, interaction videos, and an optional 3D view. The purpose of the mockup is not to define one fixed implementation, but to show how the guidelines could work together in a coherent product presentation.



COMFY HEAVYWEIGHT T-SHIRT

€ 29 99

Size

XS | S | M | L | XL | XXL







ADD TO CART

DETAILS +

SIZE & FIT +

EXPLORE THE FABRIC −



scrunch

see how the fabric creases



stretch

see how much the fabric gives



drape

see how the fabric falls and moves



view in 3D

see the fabric with more depth

5.3 Design guidelines for online fabric presentation

The guidelines are derived from the combined literature review, prototyping process, exploratory tests, and quantitative study. Some are directly supported by empirical findings, while others are design implications drawn from recurring observations across the project. Together, they describe how online fabric presentations can provide richer material information while remaining clear and interpretable.



1. Use a clear neutral view as a dependable reference point

A fabric presentation should include at least one clear, evenly lit view with a neutral colour impression. In the exploratory tests, standard photographs already provided a useful baseline impression of the garments, even if they did not communicate every fabric property in the strongest way. The quantitative study also showed that the Diffuse lighting type supported more accurate judgments of colour lightness than the warmer, more directed lighting condition. A neutral reference view is therefore important as an anchor for colour-related judgments and overall appearance, especially when additional views show the garment under more idiosyncratic conditions.



2. Supplement with complementary views to provide distinct fabric cues

Additional still-image views should be used purposefully, not simply to increase the number of product images. The exploratory tests suggested that different visual situations can reveal different aspects of the fabric: directed lighting, folds, shadows, and draped views can make the fabric's structure, surface, and optical qualities easier to inspect. However, the quantitative study did not show a general benefit of adding a second lighting view. Complementary views should therefore only be added when they provide a distinct and interpretable cue that the reference view does not show clearly. In the mockup, the standard flat view and model/mannequin view have been amended with a drape view and a close-up view. The mannequin and drape views also show they have an alternate lighting view.



3. Keep comparable views visually consistent

When multiple image views are meant to be compared, they should ideally be visually consistent except for the specific aspect that is intended to change. Differences in lighting, viewpoint, background, or garment positioning can all affect how the fabric is interpreted, making it unclear whether a perceived difference comes from the fabric itself or from the presentation. This became apparent during prototyping and the exploratory tests, where changes in lighting and staging could make the same garment appear different across views. Additional angles or stagings should therefore ideally use the same neutral lighting as the reference view, so that the fabric's general appearance remains stable across the image set. When one variable is deliberately changed, for instance the lighting condition, the other aspects of the view should remain as consistent as possible. In the mockup, all default pictures are shown under "diffuse" lighting. The pictures that are under different lighting are alternate versions of existing views.



4. Make visual differences between views explicit and interpretable

Additional views should not leave the viewer guessing why the garment looks different. In the exploratory tests, multiple lighting conditions could be helpful when they revealed different fabric cues, but they could also create confusion when participants were unsure which appearance to trust. The quantitative study also showed that adding a second lighting view did not generally improve accuracy or confidence. Therefore, when views differ in lighting, staging, angle, or interaction, the viewer should be able to understand why they are different and what each view is meant to reveal. Without such framing, additional views may feel inconsistent and confusing instead of informative. Clear labels, icons, or short captions could help users interpret additional views as purposeful fabric information rather than as inconsistent product imagery. In the mockup, this is implemented with a toggle switch and with explanations for the video types.



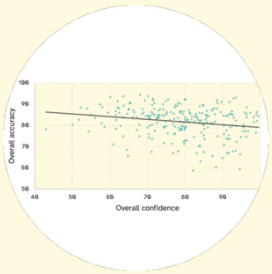
5. Adapt the presentation to the specific garment and properties that are difficult to judge

Fabric presentation should not follow one fixed recipe for every garment. Both the exploratory and quantitative studies indicated that the specific garment influenced how accurately or confidently fabric properties could be judged. Some fabrics may have properties that are especially important, difficult to convey, or unusual. In those cases, additional views or presentation techniques should be selected based on what needs clarification for that specific garment, rather than added uniformly across all products. For example, a glossy fabric may benefit from a lighting view that reveals reflections, while a stretchy or thin fabric may require a video or draping view to show how it behaves.



6. Use alternate presentation techniques as support

Interaction videos and depth-based views can be useful additions when still images do not sufficiently communicate the relevant fabric qualities. In the exploratory tests, interaction videos were ranked highly and appeared promising for showing behaviour such as stretching, creasing, drape, and movement. These videos should ideally include multiple complementary gestures to convey different qualities. Depth-based techniques like 3D photos also appeared useful for interpreting folds, structure, and spatial form. However, these techniques were not tested quantitatively in the final study, and their optimal implementation remains uncertain. They should therefore be treated as optional supporting techniques rather than universal requirements, and should be selected based on the specific fabric qualities they are meant to clarify. In the mockup, they have been given a dedicated “Explore the fabric” section.



7. Design for accurate expectations, not just certainty

The success of an online fabric presentation should be evaluated by whether it helps consumers form expectations that match the real garment, not only by whether the presentation feels informative or convincing. In the quantitative study, confidence did not function as a straightforward indicator of accuracy; higher confidence was not associated with more accurate judgments. This means that future fabric presentations should not be assessed only through perceived certainty, perceived informativeness, or purchase-related responses. Accuracy should remain an important evaluation criterion, especially when the goal is to improve the match between consumers’ online impressions and their experience of the real fabric.

5.4 Real-world relevance

While this is primarily a research project, it is a research *for design* project, so it is worth addressing the real-world relevance for online fashion retail. The project was more aimed at generating insights and design guidelines than at developing a fully validated design concept or a business case. Instead, it generated design guidelines and a product-page mockup based on literature, prototyping, exploratory tests, and a quantitative study. The real-world relevance of the outcome can therefore be considered in terms of desirability, feasibility, and viability.

Desirability

The findings suggest that improved fabric presentation could be meaningful for consumers because fabric properties can be difficult to infer accurately from online product pages. A presentation that communicates fabric qualities more clearly could help consumers form more realistic expectations before purchase.

The project also showed that more information is not automatically better. Additional views or presentation techniques are only desirable if they help consumers interpret the fabric more clearly. If a garment appears inconsistent across images, or if it is unclear why one view differs from another, additional information may create confusion rather than understanding. The proposed guidelines therefore focus on clear, interpretable, and targeted fabric cues rather than simply adding more media to the product page.

Feasibility

The proposed guidelines do not aim to radically transform the online shopping interface. Instead, they translate the project findings into practical improvements that could be incorporated into existing online fashion retail practices. This reflects the project's findings: more advanced or unusual presentation technologies did not automatically provide a clear advantage over simpler and more familiar presentation methods, and additional visual information was only useful when it remained clear and interpretable. The outcome therefore focusses on enriching product pages with select fabric-specific enhancements, rather than on a technology-push solution.

The proposed guidelines are therefore technically feasible within current online retail practice. Many recommendations build on presentation elements that already exist in product pages; that is, product photography, thumbnail galleries, zoom functions, close-up images, videos, and product information sections. The proposed mockup does not require a completely new shopping environment, but adapts familiar product-page structures to communicate fabric properties more deliberately.

However, implementation would require more standardised production workflows. For example, using a neutral reference view and additional complementary views requires careful control of lighting, framing, colour, garment positioning, and image editing. Interaction videos are also feasible with current technology, but would need consistent staging so that differences in force, speed, or gesture do not distort the perceived fabric behaviour. Depth-based views, such as 3D photos or 3D viewing, are more complex, both because they require additional production effort and because their full benefit may depend on viewing technology that not all consumers have access to, i.e., a VR or 3D headset. They may therefore be more be more realistic as optional enhancements for selected garments than as a standard feature across all product pages.

Viability

From a retail perspective, the guidelines are most viable if they are applied selectively. Producing additional images, videos, or depth-based views for every garment may require too much time and cost, especially for fast-moving collections. However, the approach could be worthwhile for garments where fabric perception is particularly important, uncertain, or difficult to communicate through standard images alone.

The potential value lies in improving the match between consumers' online expectations and their experience of the real garment. This could support more confident and better-informed purchase decisions, and may contribute to reducing dissatisfaction or returns caused by unexpected fabric qualities. However, this project did not directly test purchase behaviour, return rates, or commercial

performance. The viability of the proposed guidelines would therefore need to be evaluated in future work with retailers and consumers in a real online shopping context.
Although the project was framed around online fashion retail, some of the guidelines may also be relevant for private second-hand sellers, who often need to produce their own garment imagery. In this context, simple recommendations such as using a neutral reference image, keeping views visually consistent, and adding purposeful complementary views could be useful even without professional production resources.

Overall, the proposed guidelines and mockup translate the project findings into a practical direction for improving online fabric presentation. Rather than proposing a single superior technology, the outcome emphasises the careful selection, combination, and explanation of visual cues that help consumers form more accurate expectations of fabric properties. The final Chapter 6 concludes the project by summarising its main contributions and outlining directions for future research.

6 Conclusion

6.1 Project conclusion

This project set out to explore how online presentation can better communicate fabric properties, with the aim of helping consumers form expectations that more closely match the real garment. Rather than developing one final ready-to-implement commercial concept, the project took an iterative research-through-design approach: first exploring relevant fabric properties and presentation possibilities, then testing promising directions through increasingly focussed prototypes, and finally evaluating one selected direction quantitatively.

Across the project, the findings suggest that the communication of fabric properties online depends strongly on the visual cues a presentation provides but also that different properties depend on different cues. Optical and colour-related properties, surface-related properties, and more structural fabric qualities do not all benefit from the same presentation choices. No single visual setup is likely to be optimal for communicating all relevant fabric properties equally well.

The quantitative evaluation showed that varying the light condition did not lead to a general improvement in either perception accuracy or confidence. Only colour lightness was significantly affected by lighting condition, with the Diffuse and Both conditions supporting more accurate judgments than the Focus condition. Also, confidence and accuracy did not move together in the expected way: higher confidence was associated with lower perception accuracy overall. That suggests that a presentation can feel clear, convincing, or informative without necessarily helping consumers form more accurate expectations of the real fabric.

Taken together, the project suggests that improving online fabric presentation is not simply a matter of adding more information or visual variation. The central challenge is to provide cues that are relevant, complementary, and still easy to interpret. Richer presentation is only useful when it helps viewers form more accurate and better calibrated expectations of the material they will receive. The main contribution of the project therefore lies not in identifying one universally superior presentation technique, but in clarifying a set of design-relevant principles for communicating fabric properties more effectively online.

6.2 Recommendations for future work

Future work could extend this project in several directions.

A first direction is to test a broader range of garments, fabrics, and presentation contexts. This study used a deliberately reduced garment set and a relatively constrained lighting comparison to keep the results interpretable. Future studies could investigate whether larger differences in visual context, such as indoor versus outdoor views, scene context (including objects in the scene that could be used as visual references), or a broader set of complimentary viewing situations, produce stronger effects on perception accuracy and confidence. It would also be valuable to test whether the findings generalise beyond plain T-shirts to other garment categories and fabric types.

A second direction is to further investigate richer forms of presentation beyond still images. The quantitative phase focussed on still images to test one presentation principle, but the exploratory also indicated potential in formats like interaction videos, 3D viewing, and other techniques. These were not exhaustively investigated in this project, but they could benefit from further design divergence, iterations, and evaluation not only on how informative they seem, but also on whether they actually improve judgment accuracy.

A third direction is to investigate more interactive or multisensory presentation more directly. During the exploratory phase, the question arose whether user control over a presentation might help viewers interpret fabric behaviour more effectively. For example, in interaction videos, it remains unclear whether passive playback is preferable, or whether allowing users to control a movement themselves could support a more embodied understanding of the fabric's behaviour. Earlier work has explored interactive textile presentations called "Shoogles" (Overmars & Poels, 2015), but this remains relatively underexplored, especially given the maturation of web and mobile interaction technology since that work. Future studies could therefore diverge in the design of interactive presentations or compare passive and interactive presentation more directly. They could also examine whether additional (multisensory) cue types, such as sound in interaction videos, help communicate certain surface qualities more effectively. Directions like pseudo-haptic or vibrotactile additions may also be worth exploring, although these non-visual directions were not examined in this project.

A fourth direction is to examine how imagery and text can work together. This project focussed on visual presentation, but textual descriptions may help consumers interpret what they see, and prior work suggests that textual haptic information can positively influence product perception even if it does not fully replace touch (Rodrigues et al., 2017). Future work could investigate whether carefully formulated descriptors, explicit property scales, or interpretive guidance help consumers understand how to read fabric imagery; for example how the direction of drape folds can indicate differences in stiffness. This may be especially relevant because the present study asked participants to judge clearly defined properties, thereby giving them an interpretive framework that ordinary online shoppers may not have. It would therefore be valuable to test whether making such property dimensions visible, with brand-supplied or reviewer-supplied ratings, supports forming more accurate expectations.

A fifth direction is to test more integrated presentation concepts in a fuller shopping context. This project isolated fabric judgment in a controlled task. Future research could examine how the proposed design principles function when embedded in a realistic product page, and whether they influence broader outcomes such as confidence calibration, satisfaction, mismatch after receipt, and return intentions.

In conclusion, this project showed that improving online fabric presentation is not simply a matter of adding more visual information, but of selecting and combining cues in ways that help consumers form expectations that better match the real garment. The resulting guidelines offer a basis for further design and research towards online fashion presentation that supports both confident and accurate assessment of fabric qualities.

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APPENDIX

Personal Project Brief – IDE Master Graduation Project

Name student David Cheng **Student number** 4555058

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Presenting fabrics online: how to increase perception accuracy?

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Domain: Online apparel retail

Situation: Some fabric properties are difficult to convey online (Jang and Ha, 2023), which can lead to a mismatch between buyers' expectations and their experience when they receive the real item.

Relevancy: This mismatch can be a cause to return goods, which, next to disappointment, carries with it monetary and environmental costs and effort.

Stakeholders & interests:
- Buyer: needs enough and relevant information to purchase with confidence, and then wants to be happy with the received item (matching with the expectation set during purchase).
- Retailer: might present items attractively in pursuit of sales, but choosing attractiveness over accuracy in presentation might lead to returns (de Leeuw et al., 2016). Has an interest in minimising cost and effort in creating presentation media.

Opportunities: Previous studies (Wijntjes et al., 2019) have suggested techniques for more accurately conveying fabric properties, including videos in which hands interact with the fabric, and even interactive images. These could be further expanded and validated for more different fabric and clothing types.

Limitations: Novel technologies could help, but could be prohibitively expensive or involved for the retailer to create media for every item on sale. Furthermore, it should be possible for consumers to experience the new representations with technology they reasonably have, or will have, access to.

➔ *space available for images / figures on next page*

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Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Fabric properties can be difficult to effectively convey online (Jang and Ha, 2023). The setting is primarily or exclusively sight-based, lacking the important sense of touch. The current standard way of presentation (including static images of flat-placed clothes, model pictures, and closeups) is sometimes insufficient to accurately judge certain features (Saarijärvi et al., 2017). Most literature aims at increasing sales, but not much research has yet been done into increasing the accuracy of perception of the fabric properties.
Opportunities to create added value for stakeholders:
- An increase of perception accuracy potentially leads to
  Higher purchasing confidence for buyers
  Less disappointment or buyer's remorse
  Fewer returns, less risk of refund claims for sellers
  Less waste and unnecessary transport from fewer items discarded or returned after purchase by buyers
- A more standardised way of presenting would make it easier for buyers to compare items and for sellers to create consistent and effective listings.
- If effective (new) ways of representation can be combined or incorporated into the standard presentation, without compromising their effectiveness, the added cost to the vendor would be minimised.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design an online presentation for fabrics to improve the perception accuracy of important properties for consumers in online fashion retailing.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

[EXPLORING]
What properties of clothing/fabrics are important?: literature research, (interviews/survey)
What technologies and ways of presenting might improve the perception accuracy?: literature research, ideation methods, rapid/iterative prototyping
[SETUP]
Choose which ways of presenting to compare: qualitative evaluation, (user) tests
Make comparison media & materials: digital prototyping
Set up research: compare new presentation with current: quantitative survey
[TESTING]
Perform research study
[EVALUATING]
Analyse results: statistical analysis
Conclusions, discussion, recommendations
Synthesise into redesign and guidelines: digital prototyping

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	16 October 2025
Mid-term evaluation	18 December 2025
Green light meeting	26 February 2026
Graduation ceremony	2 April 2026

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	✔
For how many project weeks	4
Number of project days per week	4

Comments:
Part-time employment to finance studies

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I enjoyed setting up an experiment and analysing the results in the DfI Research Methodology course. I would like something similarly research/science-oriented for my graduation project, in which I can refresh and improve my knowledge of statistical analysis and writing the report around it.
As one of the project' s aims is to reduce returns, the project fits my broad interest in sustainability. Since I have taken up (analogue) photography as a hobby, some of that knowledge may prove useful in this project.

I would also like to:
- Apply some of my recently learned graphic design principles on my documentation or the design itself. I aim to produce a report of a high standard.
- Gain a more advanced level of knowledge on Figma or learn to use a new software/technology (whichever is appropriate).

For project management & personal wellbeing:
- Practise asking for help & collaboration: especially being honest (to my supervisors) when I am stuck, and showing unfinished work instead of over-preparing for meetings.
- Maintain a sustainable pace and balance of work throughout the project.
- Consciously practise making process & design decisions based on what will help me progress, rather than based on what I think is expected.

Appendix B Lo-fi prototypes

B.1 Purpose of the explorations

To explore promising ways of representing fabrics, I created and compared five low-fidelity prototypes, inspired by the directions that emerged in Section 2.2. Having some initial insights into strengths and weaknesses of techniques could help while making more focussed prototypes to ask user feedback on. Most prototypes are made with two similar-looking black t-shirts with different fabric properties. This made it easier to judge whether perceivable differences are due to the presentation technique rather than from obvious differences in colour or print.

B.2 Overview of explored techniques

Technique	Main purpose	Main strengths observed	Main limitations observed
Hand interaction video	Show deformation through visible handling	Rich cues for movement-related properties	Strongly depends on gesture choice
Wigglegram	Show depth cues	Useful for folds and surface form	Static garment and sensitive to capture consistency
3D photo	Show stereoscopic depth	Strong depth impression for folds and drape	Requires viewing aid and distorts colour
3D scan	Interactive viewing	Useful for overall form and volume	Limited realism of texture and behaviour
Light sweep	Show surface response to changing light	Useful for gloss and surface relief	Static garment and labour-intensive to capture

B.3 Individual prototype explorations

B.3.1 Hand interaction video

Rationale

A hand interaction video was explored as a way of communicating fabric properties through visible handling and deformation. Prior work suggests that the way a fabric is manipulated can reveal important qualities of its hand, and that certain gestures like scrunching may be especially informative for judging textile behaviour (Atkinson et al., 2013). The decision to include hand interaction videos was also informed by earlier related graduation work by Shen (2018), in which a video of hands interacting with the product was proposed and tested as a presentation method for communicating clothing material online. Creusen et al. (2025) have also shown that interaction videos can support textile property communication. This made gesture-based video a relevant direction to include in the prototypes.

Prototype setup

The prototype consisted of a video in which a T-shirt was scrunched by grabbing and twisting it with one hand. This setup was chosen as a simple first exploration of how visible deformation might communicate fabric behaviour. To try a more interactive viewing experience, the video was not only played back normally, but also inspected by manually scrubbing back and forth through the timeline, simulating direct viewer control over the movement. This was inspired by earlier work on interactive textile presentation and by studies suggesting that user control, rather than passive viewing alone, can be important in supporting product understanding (Orzechowski et al., 2011; Overmars & Poels, 2015). The video was made for two otherwise similar-looking t-shirts to assess how well their different properties could be discerned.

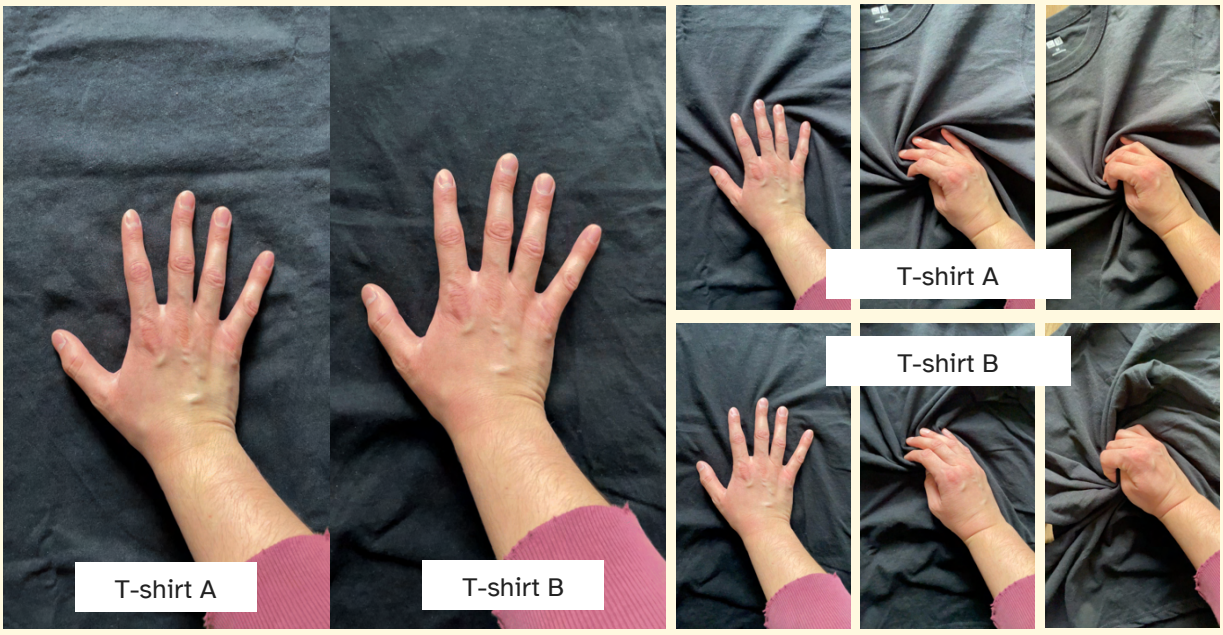


***Figure B.1**. Stills from the hand interaction videos made.*
T-shirt A was thicker and stiffer, T-shirt B was thinner and more elastic.

Strengths

The technique appeared promising for communicating properties that depend on visible deformation over time. In particular, it seemed useful for judging qualities such as stiffness, thickness, and elasticity, because the viewer could observer how the fabric folded, resisted movement, and settled into creases. Compared with static images, the video made it easier to interpret how the garment behaved under force.

Scrubbing through the timeline also seemed to give a stronger sense of control and embodiment over the inspection than passive playback alone. It made it easier to focus on specific moments in the movement and gave a somewhat stronger impression of actively examining the fabric. In addition, the number, size, and sharpness of the creases seemed to help distinguish between fabrics of different thickness or stiffness.

Limitations

The technique also raised several questions. Its usefulness depended strongly on the chosen gesture: a scrunching action may reveal some properties well (like stiffness), but not necessarily others (like transparency). This means that different properties may require different videos to be communicated effectively. Also, although the video showed how the fabric moved, the viewer still could not directly feel the force being applied, which limited the extent to which the action could substitute for real handling.

The viewing mode also mattered. Passive looping playback preserved the natural timing of the motion, but could feel somewhat frustrating when inspecting a particular moment more closely. Manual scrubbing offered greater control, but also changed the character of the experience by interrupting the continuous movement.

Implications

Hand interaction video seems especially suitable for communicating fabric behaviour that unfolds through movement and handling. The video appeared more promising for mechanical and deformation-related properties than for optical properties. Still, it effectiveness likely depends on careful choices about which specific gestures to use, and the extent to which the presentation should simulate active handling. This makes it a promising direction for further development.

B.3.2 Wigglegram

Rationale
One of the ways in which humans perceive depth is through stereoscopic vision: perceiving the same view from two slightly offset but overlapping vantage points (Howard & Rogers, 1995). It is not possible to view two viewpoints directly from a single static image, but the depth effect can still be achieved through a number of techniques; one of which is the wigglegram.
A wigglegram is a rapidly alternating set of pictures taken from adjacent viewpoints to convey depth kinetically without requiring special viewing hardware.

Prototype setup
The prototype was produced by capturing approximately six horizontally adjacent viewpoints with a single-lens camera. The images were combined into a GIF and viewed as a looping “boomerang” animation. These were also made for the same T-shirts as the hand interaction videos.



***Figure B.2**. Stills from the wigglegram. The exposure was not well controlled; changing the apparent colour shade between frames.*

Strengths
The technique appeared most useful for communicating surface form and fabric folds, especially in close-up views. It was more effective when the garment had visible depth differences like creases and folds, than when it was shown lying flat. The method also showed some potential for conveying surface qualities like smoothness and gloss, although gloss is dependent on lighting. More uniform, scattered lighting made any glossiness less evident.

Limitations
The technique appeared less obviously suitable for communicating properties that involve change over time, such as elasticity and recovery/creasability, since the garment stays static. Its effectiveness also depended on consistent lighting and camera settings across images.

Implications
Wigglegrams seem most suitable as a way to enrich close-up or draped fabric views with additional depth information. They seem less suitable as a standalone method for conveying mechanical properties.

B.3.3 3D photo

Rationale
Another way of conveying depth is though stereoscopic 3D photography: a pair of images, one for each eye. By separately presenting two slightly offset viewpoints to each eye, stereoscopic images can create a stronger sense of three-dimensionality than a single static photograph. This was explored as a way of helping viewers interpret fabric folds, drape, and surface form more clearly.

Prototype setup
The prototype was produced as a red-cyan anaglyph 3D image, because this is relatively easy to create and can be viewed with simple red-cyan glasses. As with the wigglegram, adjacent photographs were taken from slightly different horizontal viewpoints. Because these stereoscopic image pairs require more precision than wigglegrams, the camera was placed on a tripod and shifted horizontally by approximately 6 cm between the two shots. Small paper labels were physically placed in the scene to help identify matching image pairs during processing. Both parallel and converging viewpoints were tried.
The final images were viewed through red-cyan light filters, which separated the two colour channels and created the stereoscopic effect.





***Figure B.3**. Anaglyph 3D image prototype. This can be viewed with red (left)-cyan (right) glasses. Alternatively, the left and right image are shown below the anaglyph for cross-eyed viewing.*

Strengths

The technique appeared promising for communicating depth-dependent qualities like surface form, folds, and drape. Compared with a wigglegram, the stereoscopic effect felt more direct and visually stable when the image pair was well aligned, whereas the wigglegram's constant movement felt somewhat distracting and made it more difficult to focus on a specific area. It also seemed to be somewhat better at conveying qualities such as smoothness, softness, and stiffness. For example, in the jacket shown above, the stiffness of the sleeve was more apparent as it "came out of the screen", making it more intuitively clear that it was stiff enough to hold this somewhat upright shape.

Limitations

The technique appeared less suitable for properties that depend on movement or deformation over time, such as elasticity or recovery, because the garment stayed static. It was also less suitable for communicating colour accurately, as the red-cyan filters strongly distorted the colour in the image. In addition, producing comfortable stereoscopic images required more careful control of viewpoint, distance, and alignment than the wigglegram. Finally, even this relatively accessible form of stereoscopic viewing still required special viewing hardware, which limits its practical applicability and viability unless it provides a very strong added value.

Implications

Stereoscopic (anaglyph) 3D photos seem most suitable as a way of enriching fabric presentation with stronger depth cues than a standard static image. They may be particularly useful for showing folds, drape, and surface form, but seem less suitable when accurate colour representation is important. Other stereoscopic formats including VR-based viewing or polarised displays may avoid some of the colour distortion of anaglyph images, but would require more specialised viewing technology. Their practical value therefore depends not just on their perceptual benefit, but also on whether the added complexity and viewing requirements are justified.

B.3.4 3D scan

Rationale
3D scanning was explored as a way of converting a real garment into a digital three-dimensional model that could be viewed from different angles. Unlike static images, this could allow the viewer to inspect the garment more freely and to better understand its drape behaviour, folds, and spatial structure. This was explored as a possible way of supporting judgment of properties such as thickness, weight, or stiffness.

Prototype setup
The prototype was created using the MagiScan app, which generates a 3D model from optical image data captured with a phone camera. This made it possible to experiment with 3D scanning in an accessible way without the need for specialist scanning equipment. The resulting model could be rotated freely on-screen and could also be viewed in augmented reality (AR).



***Figure B.4**. Capturing process of the scan.*



***Figure B.5**. 3D scan in-app and in AR.*

Strengths
The technique appeared promising for communicating the overall three-dimensional form of the garment and for allowing inspection from multiple viewpoints. The polygon-based shape reconstruction appeared surprisingly detailed, especially considering that the scan was made using only a phone camera. This made the technique potentially useful for perceiving larger-scale folds and some aspects of thickness or weight. The possibility of placing the scanned garment into the user's own environment through AR may also give a better sense of the garment.

Limitations

The technique also showed clear limitations. While the reconstructed geometry appeared detailed, the texture quality was low, which limited the communication of finer surface qualities. In addition, it was unclear to what extent the final shape was directly measured and to what extent it was interpolated by the software. As a result, a scan could appear convincing without necessarily being a fully accurate representation.

The technique appeared less suitable for communicating optical qualities such as glossiness, because the lighting conditions at the time of scanning became effectively “baked into” the model. Highlights and shadows therefore do not respond naturally when the model is rotated or viewed in AR. It also seemed unsuitable for properties such as transparency and uncertain for qualities including smoothness, softness, or recovery, which would depend strongly on the resolution and realism of both the geometry and the texture. Moreover, although the model could be placed in AR, it did not automatically scale correctly. Theoretically, if the garment is scanned on a mannequin, it could then be “tried on” by the user in AR, but that scan would not drape or move like the real garment and would not conform to the user’s silhouette.

Implications

3D scanning seems most useful for communicating overall garment form, interpreting larger creasing, and giving a sense of control in inspection. It appears less suitable for representing fine surface qualities or material behaviour unless the geometry and visual rendering are substantially improved. As such, it may be more useful for conveying the general shape, colour, and presence of a garment than for accurately communicating the full experience of its fabric properties.

B.3.5 Light sweep

Rationale
A “light sweep” was explored as a way of revealing fabric qualities through changing illumination. While standard product photos usually show a garment under one fixed lighting condition, the appearance of a fabric can change substantially when the light direction changes. Moving highlights and shadows may help reveal surface shapes, folds, glossiness, and other optical cues that are less visible in a static image.

Prototype setup
The prototype was produced by photographing a garment from a fixed camera position while rotating a light source around it. The resulting image sequence was viewed as a looping GIF animation, allowing the effect of different lighting angles to be observed over time. These too were made for two black T-shirts.



***Figure B.6**. Stills from the light sweep prototype. With frontal lighting, the T-shirt appears flatter. When the light shines from the sides, the creases appear much more prominent.*



Strengths
The technique appeared most promising for communicating optical qualities that depend on illumination, especially glossiness. It also seemed useful for revealing folds and surface relief more clearly, because light from low angles to the side increased visibility of shadows and highlights across the garment. So, the method may help to enrich the perception of surface shape beyond what is visible in an evenly lit photograph.

Limitations
The technique appeared less obviously suitable for communicating properties that depend on deformation or movement, such as elasticity or recovery behaviour, because the garment itself remained static. Its usefulness for mechanical properties like stiffness and thickness seemed to depend strongly on whether the garment was arranged with visible folds or drape. In addition, the quality of the effect depended on capturing enough lighting steps and keeping both camera and light settings consistent throughout the sequence.

Implications
Light sweeps seem especially suitable for exploring how changing illumination can support the communication of optical and surface-related fabric qualities. They appear less suitable as a standalone method for conveying mechanical behaviour, but may become more informative when combined with other forms of presentation. The technique benefit from letting viewers actively control the light position rather than passively watching a fixed sequence. Another variable could even be added, like garment rotation, although that would multiply the number of images needed.

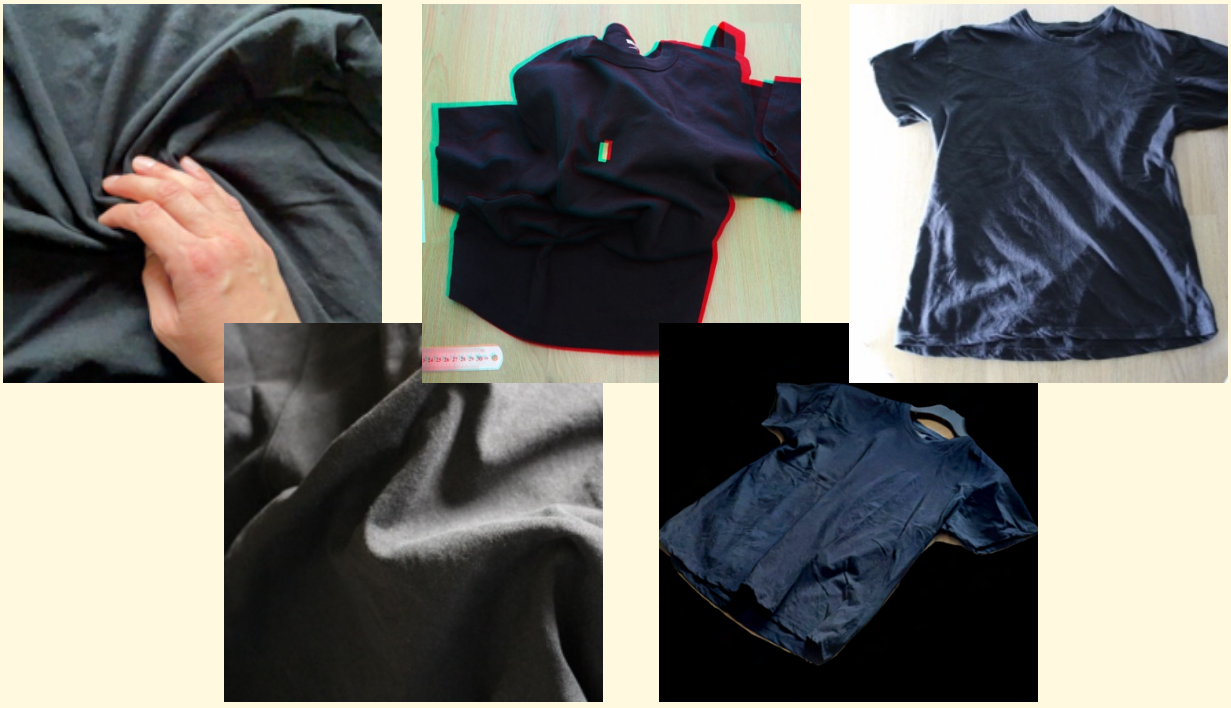
B.4 General insights

Together, the lo-fi prototype explorations suggested that different presentation techniques may be suited to different kinds of fabric properties. No single technique appeared capable of communicating all relevant qualities equally well. Instead the explorations pointed towards a distinction between techniques that primarily support judgments of surface form and optical appearance, and techniques that support judgments of deformation and material behaviour.

Depth-based techniques such as wigglegrams, stereoscopic 3D photos, and 3D scans appeared most useful for communicating folds, drape, and three-dimensional surface form. In some cases, these techniques may help viewers infer properties like thickness or stiffness through the size, number, and shape of folds. Lighting-based exploration suggested that changing illumination may be particularly relevant for gloss and surface structure. Hand interaction videos seemed more promising for properties that depend on deformation over time or physical manipulation, such as stiffness or elasticity.

The explorations also suggested that some properties depend not only on the capturing technique itself, but also on how the garment is presented in that technique. For example, elasticity may be difficult to judge in any static representation, regardless of whether depth cues are added, because the property mostly becomes apparent when the fabric is stretched. Conversely, other properties including smoothness may already be communicated well through high-quality close-up images, even without more advanced presentation technologies. Both the **technology used** and the **way the garment is staged** or manipulated play an important role in what can ultimately be perceived.

These insights were used to decide which directions were worth developing further in the medium-fidelity prototyping phase, which is described in Appendix C.



Appendix C Mid-fi prototypes

This Appendix describes the mid-fi prototypes made for the exploratory tests in Chapter 3. Compared to the earlier low-fidelity explorations of Appendix B, these prototypes were more refined and standardised, so that participants could meaningfully compare different fabric presentation techniques. They were not meant as final presentation concepts, but as test stimuli of sufficient fidelity for evaluating which directions appeared promising for further development.

C.1 Overview of the included techniques

The exploratory tests included five presentation techniques:

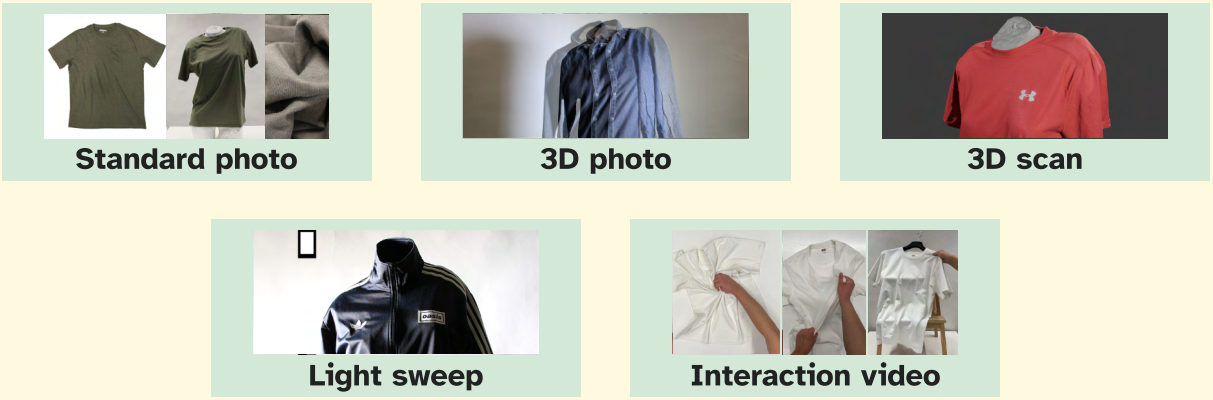


***Figure C.1**. Overview of the techniques included in the exploratory tests.*

Photographs for the prototypes were taken with a Canon EOS100D with an EF-S 18-55mm lens, unless otherwise specified. Most prototypes were viewed on a laptop (Apple MacBook Air M2) on full brightness, with True Tone and Night Shift off. The tests took place in a studio at the Industrial Design faculty of TU Delft under overhead lighting and daylight.

C.2 Standard photos

Purpose

"Standard" photo sets were included as a representation of typical online garment presentation, inspired by the visual elements that were found in Section 2.2.1. This provided a reference against which the more experimental techniques could be compared.

Stimulus design

For each garment, a set of three photographs was shown: a lay-flat image, a mannequin view, and a close-up detail image.

Production setup

- **Flat**: the garment was laid out on a white background and photographed from above.
- **Mannequin**: a frontal view of the garment on a white plaster female mannequin. A mannequin was used instead of a human model to ensure a consistent pose and to avoid possible visual calibration effects from skin tones.
- **Close-up**: an image showing detail of the main fabric, with creasing to provide shape and drape cues. A recognisable structure like the collar was kept in view as a reference for size and shape.

Variations

For garments B, D, and J, the original webpages were still available. Where possible, the original photos were used. During the exploratory tests, I also tested combinations of original and my own images.

Multiple versions were made. For the lay-flat and closeup views, versions with and without flash were taken. For the mannequin view, versions were made under diffuse overhead lighting, with one directed light source, and with two directed light sources. For each image and garment, the version that appeared most natural and visually accurate was selected.

Viewing conditions

The three images were displayed side-by-side on a full-screen page. Participants were allowed to zoom in on the images.

Practical notes and technique-specific limitations

Even while taking these relatively simple "standard" photographs, it became very apparent that there is no standardized capturing method that works equally well for all garments and all properties at once. While compiling the photo sets, decisions already have to be made that could influence perception.

For example, flash photography may accentuate glossiness but exaggerate surface irregularities and alter colours. Photographs without flash may produce a more natural colour impression but hide glossiness (see Figure C.2). Some colours, like black, pose challenges since exposing for accurate colour will make it too dark to distinguish details, while exposing for the visibility of features will make the black look more like grey.

Another consideration was whether to present a visually cohesive set of pictures or a more diverse set. A cohesive set gives a clear and consistent impression but may fail to present some properties accurately. A more varied set may communicate specific properties better, but can make the garment appear inconsistent from one image to the next.



***Figure C.2**. Lighting can make the same garment look quite different and support different property judgments. The left three images are from the official product page (Adidas, n.d.) and present the colours accurately, but hide the glossiness that is apparent from the fourth image under directed lighting.*

Note. The left three images are adapted from *Tour Firebird track top*, by Adidas, n.d., https://www.adidas.com/us/tour-firebird-track-top/KT3456.html. Copyright 2026 by Adidas America, Inc. The rightmost image is an original photograph by the author.

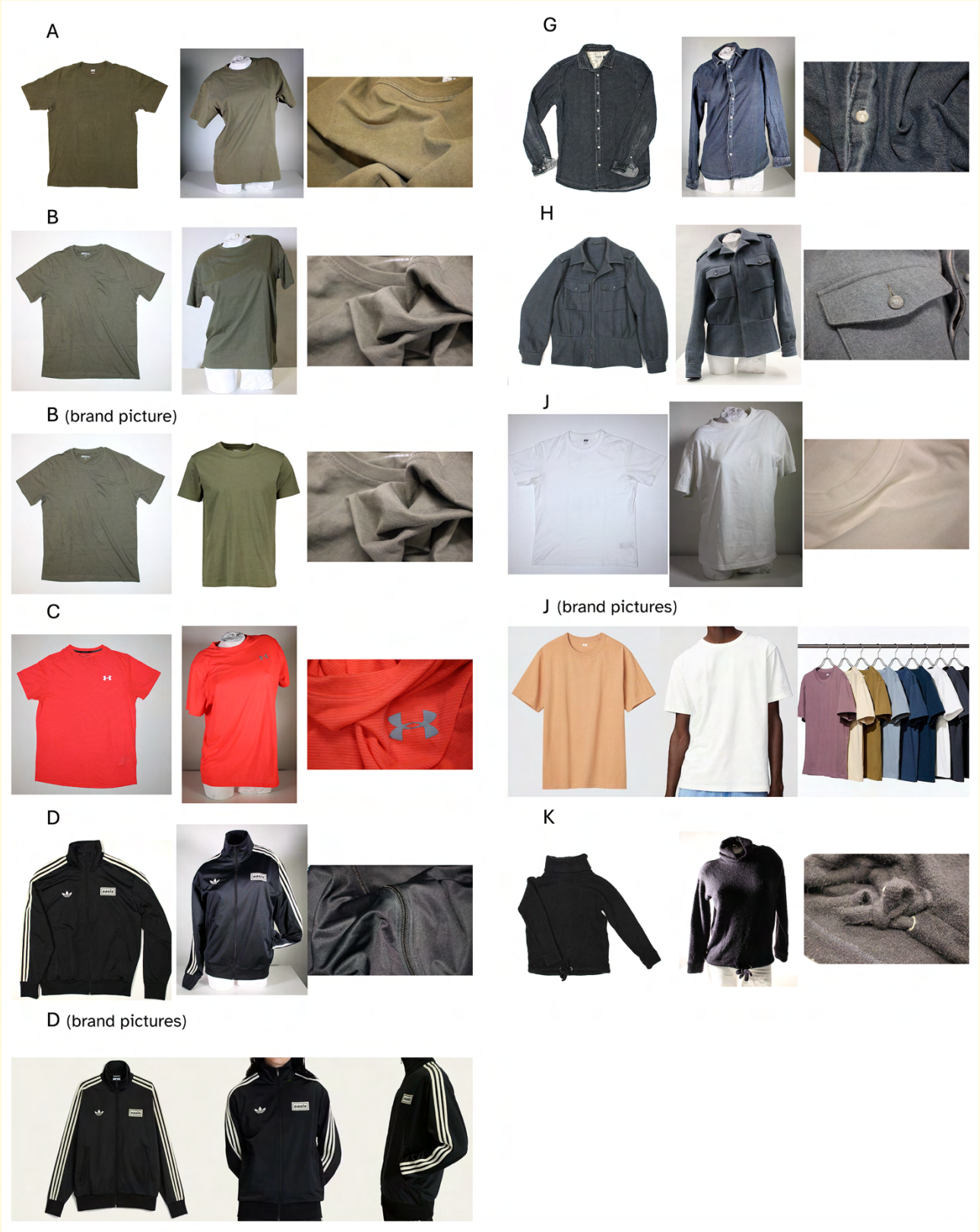


Figure C.3*. Overview of the Standard photograph stimuli used in the exploratory tests. Eight garments were prototyped. For some, original brand-made pictures were available, which were included as an alternate variation.*

C.3 3D photos

Purpose

3D photos were created to examine whether supporting depth perception would offer an advantage over standard photos. The underlying idea was that improved depth cues might help viewers interpret how a fabric folds and drapes, and infer qualities like thickness and stiffness from the size, flow, and number of creases. Instead of the wigglegrams and anaglyphs from the Lo-fi prototypes, these were made as stereoscopic image sets viewed through a 3D headset. This allowed stable viewing of the 3D effect without losing colour.

Stimulus design

For each garment, a set of two stereoscopic 3D photos was shown: a mannequin image and a close-up detail image. The lay-flat image used in the Standard photos was omitted, as earlier low-fidelity explorations suggested a flat view offered little added value in 3D (see Section B.3.2).

Production setup

Stereoscopic 3D photo sets were made by taking one photo for the left eye and one photo for the right eye.

- **Mannequin**: a frontal view of the garment on a mannequin. Two otherwise identical left and right images were taken 6 cm apart: starting in the centred position used for the standard photo, then shifting the camera -3cm and +3cm. The camera was moved linearly without angle correction.
- **Close-up**: a detail image of the main fabric on a neutral white background. The fabric was laid out in such a way that there were folds visible to ensure sufficient depth to be perceived. A pen was placed in the foreground as a size reference, to make scale easier to interpret when viewed in the 3D headset. Distance between the left and right images was reduced to 4 cm and the camera angle was adjusted to keep the same point centred in the picture. This was done because the 6cm spacing with parallel camera positions made the left and right image too different, which reduced viewing comfort in the headset.



***Figure C.4**. Capturing setup of the close-up photos. The camera is mounted on a rail on the tripod, which allows for precise and repeatable side-to-side movement.*

Variations

Three versions were made for the mannequin views: diffuse overhead lighting, one directed light source (at approximately 45° between subject and camera), and two directed light sources (at 45° on both sides). During the exploratory tests, different variations were shown to the participants to compare their performance.



Viewing conditions

Pictures were shown through an ION VR 360 3D viewer on an iPhone 12 mini at fixed maximum brightness, with True Tone and Night Shift turned off. Participants could adjust the lens positions individually. Figma mirroring with a laptop was used to switch between images without requiring participants to remove the headset.

Practical notes and technique-specific limitations

Producing stereoscopic images required more precision than standard photography, as small differences in camera position, framing, and angle can affect viewing comfort. This was especially the case for the close-up views, where a full 6 cm shift caused the left and right image to differ too much. This led to eyestrain and difficulty perceiving a stable 3D image in the headset.

Image composition also mattered. The 3D effect worked best in the centre of the field of view, while towards the edges sharpness decreases and visual artefacts become more noticeable. For this reason, it was preferable to keep the garment away from the image edges. However, this also limited the maximum usable zoom level, and thus the amount of visible detail. Detail is also limited by the resolution, as viewing phone screen at close distance through the magnifying lenses made individual pixels somewhat noticeable.

Close-up views needed sufficient height differences (folds) for the stereoscopic effect to be noticeable. The fabrics were therefore arranged deliberately to create visible depth. Including a familiar object as a scale reference also proved useful, because the headset presentation filled much of the viewer's field of vision and could otherwise make the size of the depicted fabric difficult to judge.

A further limitation of this technique is that it requires specialised viewing hardware. The headset had to be adjusted by each participant, and using it could be cumbersome for participants wearing glasses.



***Figure C.5**. Stereoscopic 3D image pairs, reversed here for cross-eyed viewing in the report. During the exploratory tests, the images were presented in normal left-right order.*

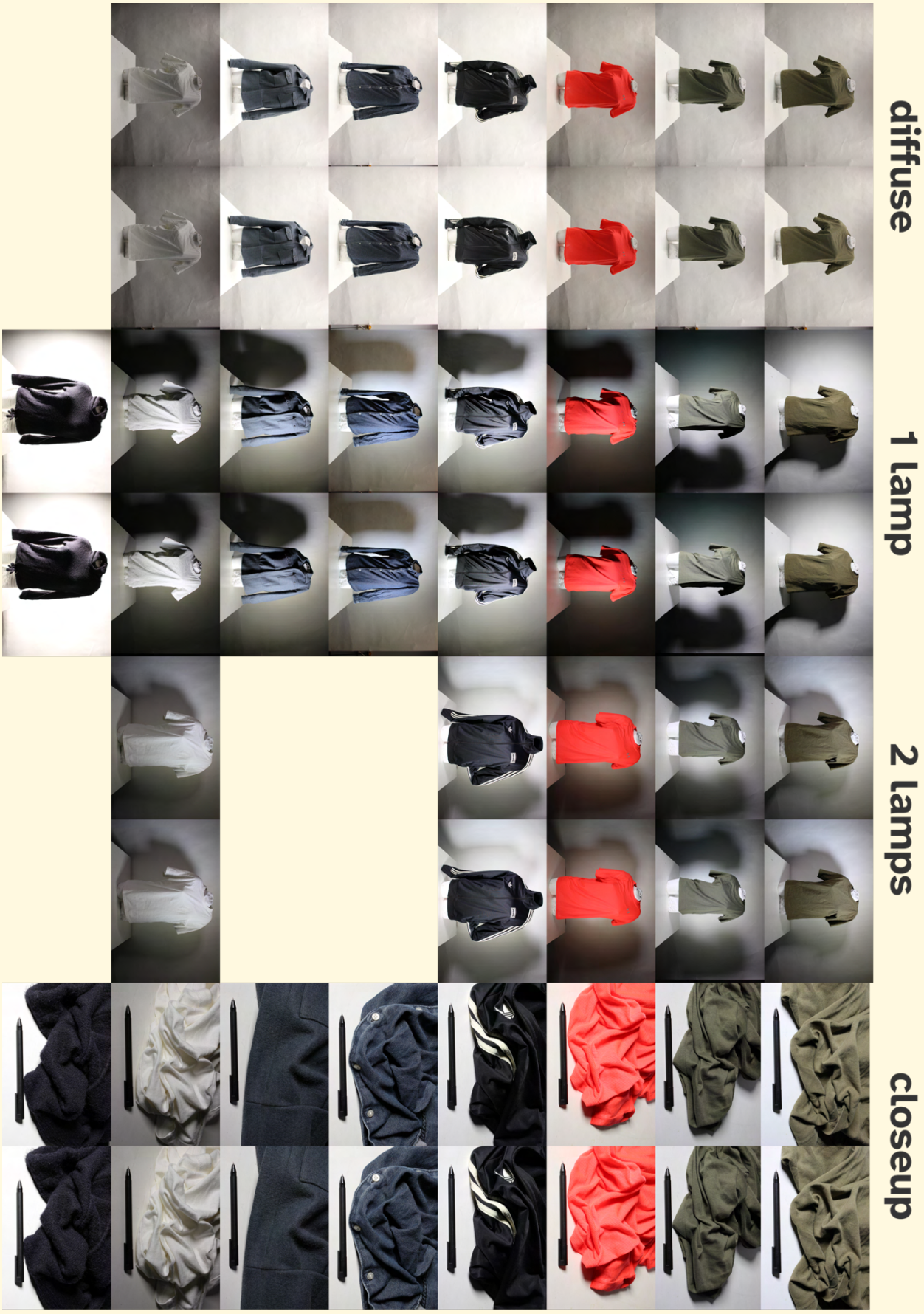


***Figure C.6**. Overview of the 3D photo stimuli used in the exploratory tests. Eight garments were prototyped. For some garments, alternate versions with different lighting setups for the mannequin view were also included.*

C.4 3D scans

Purpose

The third technique was 3D scanning. This technique was included to explore whether freely viewing a garment as a three-dimensional object, from any angle, could improve how well a user can judge the shaping and creases of the fabric. This could be particularly relevant for judging mechanical properties like stiffness, similarly to the 3D photos. Compared to the Lo-fi prototype, these were made using higher-end equipment and with the garments placed on a mannequin, in order to obtain a higher-quality and more volumetric representation.

Stimulus design

3D scans were produced for garments A, B, C, D, and J. Not all available garments were scanned due to time constraints.

Production setup

Garments were placed on a mannequin on a rotating platform. The scans were made using an Artec Eva 3D scanner and processed in Artec Studio 20 before being exported as 3D model files. The models were then viewed in Blender. Because the scans did not contain any reflectivity data, they appeared unrealistically glossy by default. Roughness was increased in the Blender preview to approximate their more matte real-life appearance. The background colour was set to a medium grey.





***Figure C.7**. Production setup for the 3D scans. The garment was placed on a mannequin on a rotating platform. The small image above shows the unrealistic glossy appearance of the 3D model.*

Variations

Two viewing modes were used. In the **material preview**, the garment is displayed with a default even lighting. In the **render preview**, the lighting is manually configured. For this mode, three spotlights were placed above the model in a triangular arrangement, creating more directed lighting and stronger shadows than in the material preview. Different participants were shown different view modes in the explorative tests.

Viewing conditions

Participants could freely rotate and zoom the models.

Practical notes and technique-specific limitations

The scans captured the overall geometry in considerable detail, but surface appearance was less reliable. Some colours could shift, and areas inside folds or underneath sleeves were difficult to capture because the scanner required a straight line of sight. While the scanner could capture flat areas and general surface shaping well, fine features like fabric edges were too small to be mapped accurately.

Producing usable scan models also required both manual scanning skill and substantial post-processing, making this a relatively time and labour-intensive technique.





***Figure C.8**. Example of the 3D scan prototype, shown from multiple viewpoints to illustrate the rotation and zooming of the model.*
The small additional picture above shows how some scanning data from a sleeve is missing because of scanning difficulty caused by the direct line-of-sight requirement of the scanner.



Figure C.9. *Overview of the 3D scan stimuli used in the exploratory tests. Five garments were scanned. For each garment, two variants were used: one viewed in the material preview (containing the garment as scanned), one in the render preview with added spotlights from above.*

C.5 Light sweeps

Purpose

The fourth technique tested was a *light sweep*: an interactive presentation in which a light source can be rotated around a stationary garment. This technique was inspired by earlier work by Xie (2016) on varying illumination to reveal material qualities. The underlying idea was that seeing folds and surface reflections under changing light might help viewers interpret the depth, shape, and surface of the fabric. It was expected to be potentially useful for mechanical properties such as stiffness and thickness, but also for optical and surface properties such as glossiness or smoothness. Compared to the Lo-fi prototype, this setup was more controlled, included more viewpoints, and used a mannequin for greater surface relief.

Stimulus design

Each light sweep consisted of a sequence of images of the garment on a mannequin, captured from a fixed camera position while the light source was moved around the garment. Participants could interactively move back and forth between the images, allowing them to inspect how shadows and highlights changed across the surface.

Production setup

The garment was set up on a mannequin, with the camera facing it. A single studio lamp at 130 cm distance from the centre of the mannequin served as the moving light source. The lamp was moved in an arc from -115° to +115° around the garment, and a photograph was taken every 5°. A length of string tied between the lamp and the rotation point ensured consistency in distance and angle.

Camera settings were kept fixed throughout the sweep. Shutter speed was adjusted for adequate exposure at approximately 45° lighting and then kept constant.

The resulting images were cropped and uploaded into a p5.js sketch that added a graphic slider element which controlled the picture shown, and thus the angle of the light. This p5.js implementation was adapted from an earlier prototype developed by Xie (2016).

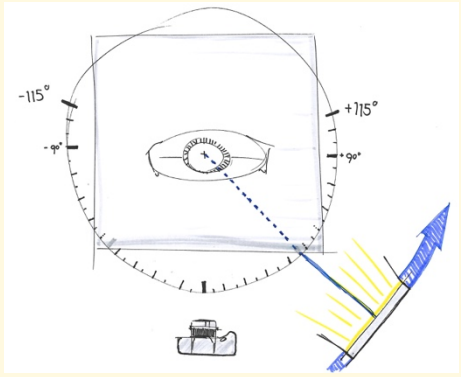


***Figure C.10**. Production setup for the light sweeps.*

Viewing conditions

These prototypes were viewed in a browser as an exported p5.js sketch. The light source could be moved by dragging a slider back and forth with the cursor.

Practical notes and technique-specific limitations

This technique depended strongly on precise physical alignment during image capture. Around the centre of the sweep, the lamp moved close to the camera and tripod, which made positioning difficult. In a few cases, the lamp touched the tripod slightly, causing a small shift in camera angle that became visible in the final prototype. Although the lamp passed behind the camera, the light source was large enough that the camera did not cast a noticeable shadow onto the garment.

Keeping the exposure constant throughout the sweep caused some dark or overexposed spots in the extreme positions. Adjusting exposure per frame might improve visibility, but it might also reduce the consistency of the simulated rotating lighting effect.

The production process was relatively labour-intensive. The light had to be moved manually for each step, after which the images had to be imported and cropped, grouped and ordered correctly, and uploaded into the interactive prototype. The technique also involves a trade-off between smoothness and effort: a smaller angular step size would create a smoother interaction, but would also require capturing and processing more images.

For future iterations, it may be worthwhile to build a more robust lighting rig or a static installation with multiple individually controllable light sources. This would improve consistency and reduce production effort.

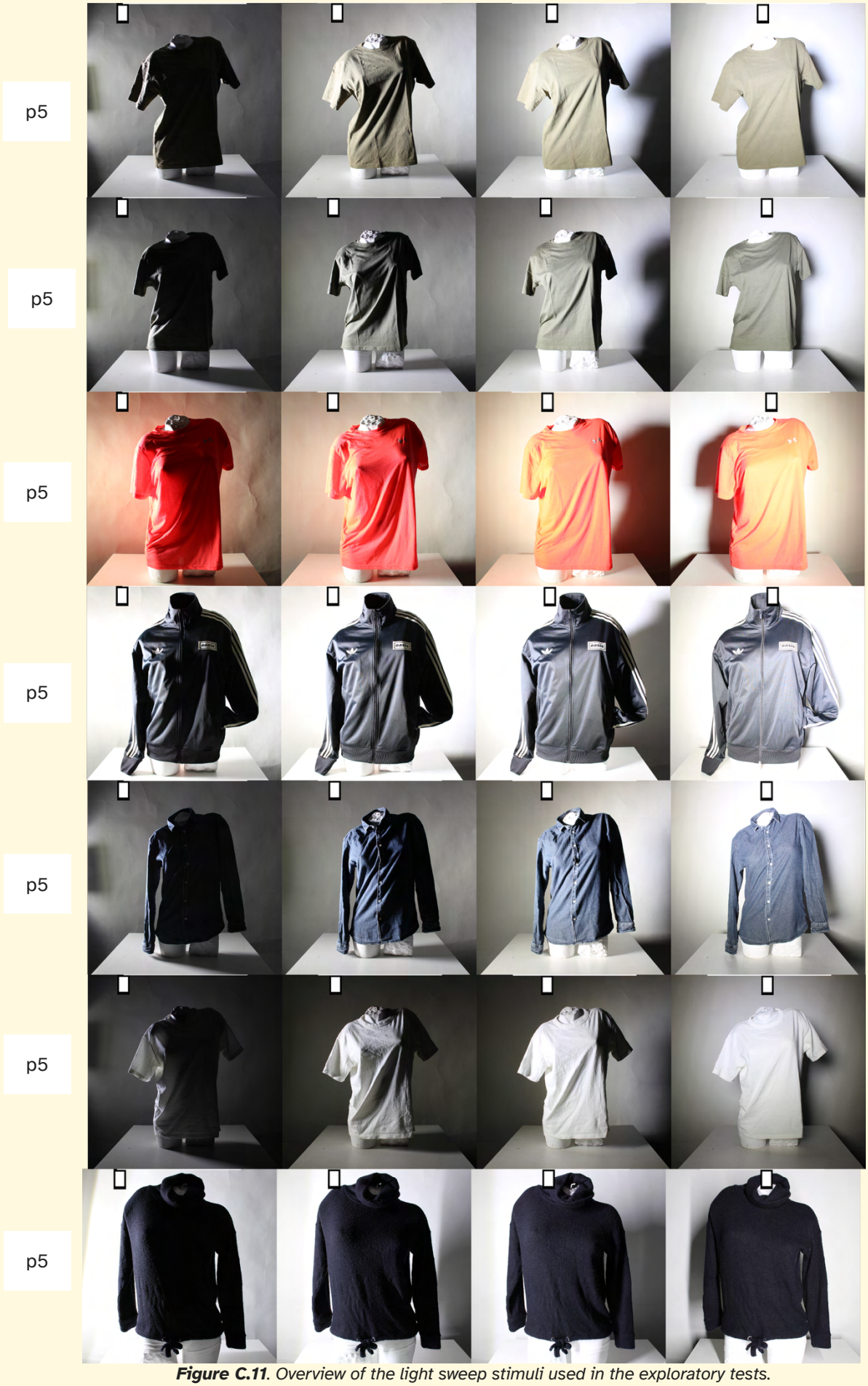


***Figure C.11**. Overview of the light sweep stimuli used in the exploratory tests.*
Seven garments were prototyped; four positions of each are shown. The "p5" boxes link to the prototypes.

C.6 Interaction videos

Purpose

The final presentation technique consisted of videos showing hands interacting with the fabric. This approach was based on earlier work by Creusen et al. (2025) suggesting that such videos may help communicate textile qualities. Seeing how the fabric moves, deforms, and responds to human hands could provide viewers an intuitive impression of its properties. Compared to the Lo-fi prototype, two more gestures were added to the scrunch to cover a more complete range of manipulations.

Stimulus design

Three videos were made for each garment: a scrunch video, a stretch video, and a drape video.

Production setup

The videos were filmed at 1080p, 60fps on an iPhone 12 mini mounted on a stand. The specific motions chosen were inspired by those used by Creusen et al. (2025).

- **Scrunch**: the garment was laid on a flat white surface, grasped with one hand, and twisted. This interaction was expected to be relevant for properties like stiffness and creasability.
- **Stretch**: two hands picked up one layer of the fabric and stretched it horizontally, vertically, and diagonally. Multiple directions are included because the weave or knit structure of a fabric can make it anisotropic. This video was expected to be particularly relevant for elasticity.
- **Drape**: the garment was hung on a clothes hanger and shaken in front of the camera, then draped over a stool. This interaction was expected to be suitable for drape-related properties like stiffness and thickness.

Playback mode

In the earlier low-fidelity video prototype (Section B.3.1), manually scrubbing through the timeline appeared to give a stronger sense of active inspection, because it allowed the viewer to control the movement directly and enabled focussing on particular moments in the movement. However, automatic playback preserves temporal cues from speed and acceleration of the fabric more naturally. For the exploratory tests, the videos were presented as passively viewed looping clips. Whether user-controlled scrubbing improves the interpretation of fabric behaviour remains an open question for future research.

Viewing conditions

For each garment, the three interactions were shown simultaneously side by side on a full-screen presentation slide. the videos played and looped automatically.

Practical notes and technique-specific limitations

This technique had the advantage of showing deformation over time, which made it particularly suitable for properties that depend on movement or handling. Even so, their informativeness depended strongly on the specific gesture that was shown.

Standardising the gestures was important, but came with challenges. Small differences in hand speed, force applied, or movement path might change how the fabric appeared to behave. This was especially relevant for the stretch videos, where viewers could *see* the hands pulling on the fabric but could not *feel* directly how much force was being applied. As a result, part of the interpretation depended on visually inferring the strength. Consistency in filming was necessary to keep differences between garments interpretable. Although it would be possible to mechanically standardise interactions like stretching, highly standardised textile tests do not always match subjective experiences well.

In future iterations, the range of interactions could be expanded and examined further to determine which interactions are most suitable for communicating which properties, and how the issue of (force) reference might best be addressed. This was beyond the scope of the this project, in which video was considered as one of several presentation techniques rather than as a standalone focus.



Figure C.12. *The interaction videos consisted of three videos: scrunch, stretch, and drape. Three frames of each video type are shown here.*



***Figure C.13**. Overview of the interaction video stimuli used in the exploratory tests. Three videos were made for eight garments; one frame per video is shown here.*

Appendix D Hi-fi prototypes

This Appendix documents how the image stimuli for the quantitative test in Chapter 4 were produced. It describes the photographs used, the capture setup, and the way the stimuli were presented in the p5.js interface.

D.1 Image sets

Image sets were made of four garments. Each image set contained two views, and each view was photographed under two lighting conditions. This resulted in a set of images that could be shown either as a single-light presentation (Diffuse or Focus) or as a multiple-light presentation (Both).



***Figure D.1**. Overview of the images used as stimuli in the quantitative study.*

D.2 Capture setup

All stimuli were photographed in a lab at TU Delft without windows, ensuring consistent lighting.

Views

Two views were used: one frontal view on a mannequin and one draped view over a stool. The frontal mannequin view provided a familiar presentation of the garment and a clear reference for overall shape and proportions. The draped view was added to reveal folds, drape, and other three-dimensional fabric behaviour. This choice was informed by earlier findings that three-dimensional fabric cues can support fabric judgments more effectively than flatter presentations, which mainly reveal more limited surface information (Xiao et al., 2016). No more than two views were used, because additional views would provide limited new information and would increase participant effort.

Light

Two lighting conditions were captured.

Diffuse	Overhead fluorescent lighting in the lab. Colour temperature was 4150K, measured with the Kelvin Meter app.
Focus	A Rotolight ANOVA LED floodlight, positioned at about 1.5 m from the garment and offset to one side, pointing slightly downwards at the T-shirt. Colour temperature was 3150K, set on the light source and verified with the Kelvin Meter app. The brightness of the light source was adjusted for each garment individually to obtain a somewhat comparable exposure and to avoid overexposure or clipping using the viewfinder histogram as a guide.

White balance kept fixed between the two colour temperatures to maintain the visual difference between the two image sets. The aim of the study was not to isolate the effect of light directionality alone, but to compare more consistent versus more varied presentations. Keeping white balance fixed therefore helped to make the two lighting conditions visibly distinct, although it also means that any perceptual differences cannot be attributed to light directionality and colour temperature separately.

Camera

All photographs were taken on a Canon EOS 100D DSLR with an EF-S 18-55mm lens, stabilised on a tripod. Focal length and framing were set up for the two views and kept the same between garments. Images were captured in manual mode with the following settings kept constant across garments: aperture f/8, ISO 100, manual focus, and fixed white balance on Fluorescent setting. Images were recorded in RAW+JPG format; JPG files were used directly for the final stimuli without further white-balance correction. Shutter speed was adjusted where needed between garments:

	Frontal mannequin	Drape
Green T-shirt	0.5 s	0.5 s
Black T-shirt	0.6 s	0.5 s
White T-shirt	0.25 s	0.4 s
Blue T-shirt	0.5 s	0.5 s

D.3 Stimulus presentation in p5.js

The photographs were incorporated into a custom p5.js interface that was used in the quantitative study (Figure D.2). The two images of the same garment were displayed above the rating sliders.

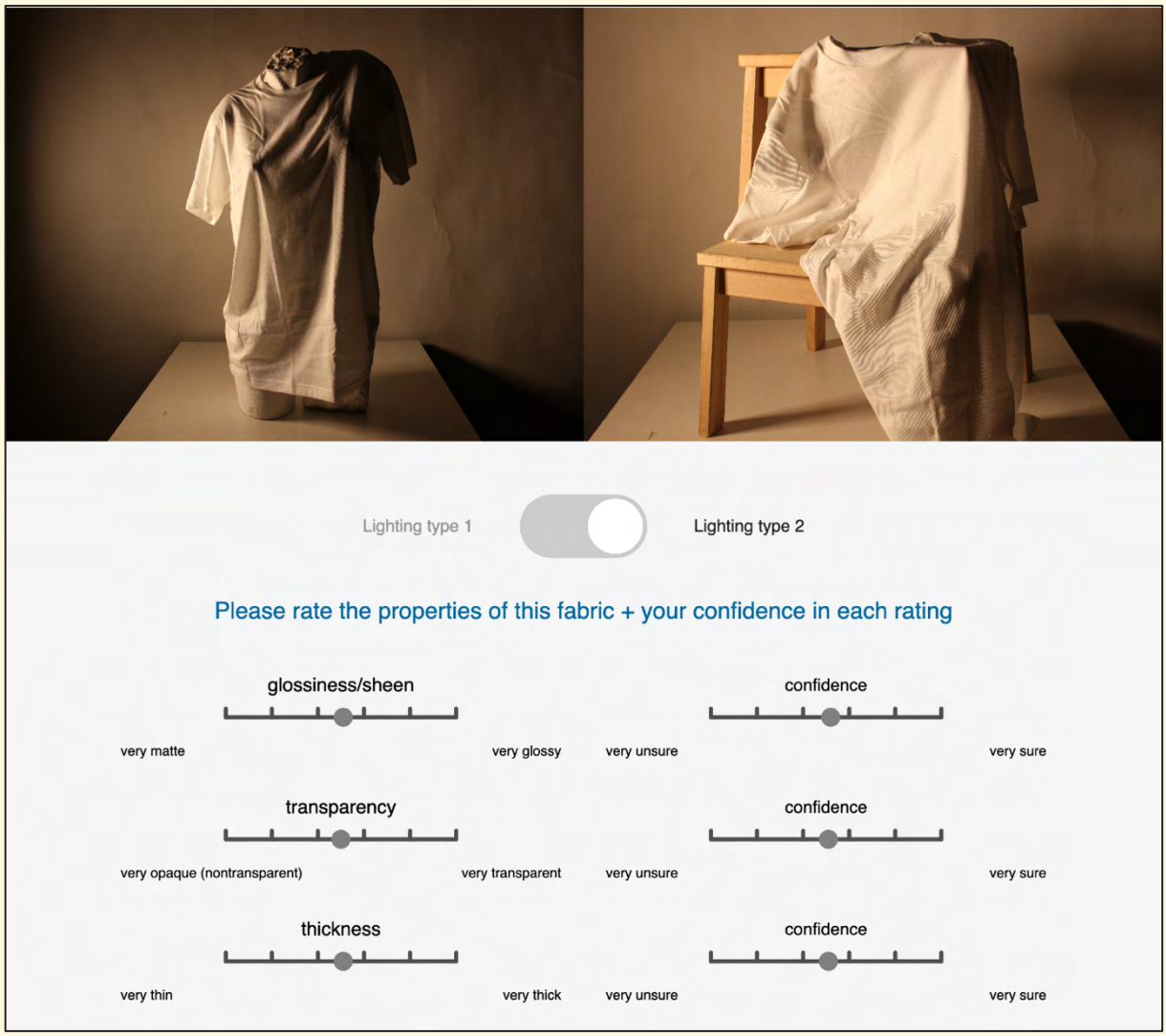


***Figure D.2**. p5.js interface in which the images were incorporated (truncated). A working example can be found at https://editor.p5js.org/dfn.cheng/full/Nuk5-Zy__.*

For the Diffuse and Focus conditions, the mannequin and drape pictures were shown side-by-side. Participants could inspect the images using a hover-based zoom function up to 300%.
For the Both condition, the same two views were shown, but the interface additionally included a toggle function that allowed participants to switch between the Diffuse and Focus versions of the garment while keeping the image positions constant. This made it possible to compare the same views under two lighting conditions directly.

D.4 Practical note

The image sets used in the quantitative study were designed as a controlled comparison rather than as a final recommended production setup. The use of the same views under two different lighting conditions helped isolate presentation differences as clearly as possible for the experiment. In real-world product photography, greater variation in view type, lighting, composition, and context may also be useful, but these possibilities were outside the scope of the quantitative test in this project.

Appendix E Real fabric tests

E.1 Introduction

In the quantitative study of Chapter 4, perception accuracy was defined as the degree of agreement between ratings based on the online presentation and baseline ratings of the real physical garments. These baseline ratings were obtained through an in-person study, in which participants judged the same set of garments directly on the same seven properties while seeing and handling them. This Appendix documents that baseline study and presents the resulting reference values used in the Chapter 4 accuracy calculations.

E.2 Participants

Thirty participants took part in the in-person study. Participants were adult students recruited from the Industrial Design faculty of the TU Delft. The sample size was chosen to obtain a reasonably stable mean baseline rating per garment and property while remaining feasible within the scope of the project.

E.3 Materials and measures

Garments

A set of four garments was used. To minimise the influence of features other than fabric itself, all garments were plain T-shirts without patterns, graphics, or major construction differences. The set was selected so that, together, the garments covered relatively low, medium, and high values across the seven properties later used in the online study.



***Figure E.1**. The four garments used in the experiment.*

Measures

The same seven properties as in Chapter 4 were rated: glossiness, transparency, thickness, smoothness, colour lightness, colour warmness, and colour saturation. Properties were rated on 100-point continuous scales with markings at every 20 points. Each scale used labelled poles to support consistent interpretation. Fuller definitions of the properties are provided in Section 2.1 and Section 4.3.4.

E.4 Procedure

The study was conducted in a TU Delft lab under consistent lighting conditions. Before the rating task, participants filled in a demographics survey, then received a short explanation of the properties and the scale format. To familiarise them with the range of garments included in the study, all garments were shown briefly before the rating task started.

Participants were presented with the four real garments one by one and were asked to rate each garment on the seven fabric properties using the 100-point scales. Participants were free to inspect and handle the garments directly during this task.

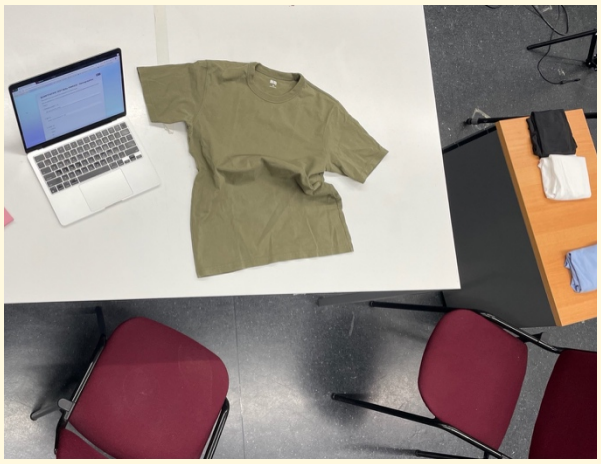


***Figure E.2**. Setup of the study.*

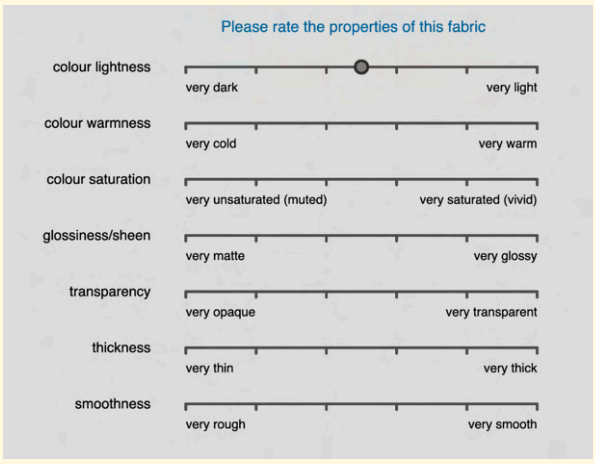


***Figure E.3**. The interface used to collect ratings.*

E.5 Data processing

Data were screened for obvious errors and outliers. One outlier was a “colour lightness” rating of 100 for the black t-shirt. As this was plausibly erroneous scale interpretation, this datapoint was removed. Other outliers were inspected but retained, as they were not clearly invalid and may reflect genuine differences in subjective perception.
Mean baseline ratings were then calculated for each garment and property.

E.6 Results

Table E.1 presents the resulting baseline ratings for the four garments across the seven properties. These mean values served as the reference values for the accuracy calculations in Chapter 4. Figure E.4 illustrates the responses.

***Table E.1**. Baseline ratings of the seven properties for the four garments on a 100-point scale.*

N = 30	Colour lightness	Colour warmness	Colour saturation	Glossiness	Transparency	Thickness	Smoothness
Green	33.63	51.47	41.23	12.77	10.00	69.67	31.83
Black	5.90	33.40	49.60	74.90	43.90	16.37	84.90
White	96.60	31.23	50.47	53.83	63.17	29.73	64.80
Blue	70.60	29.37	49.53	24.97	36.23	40.10	56.13

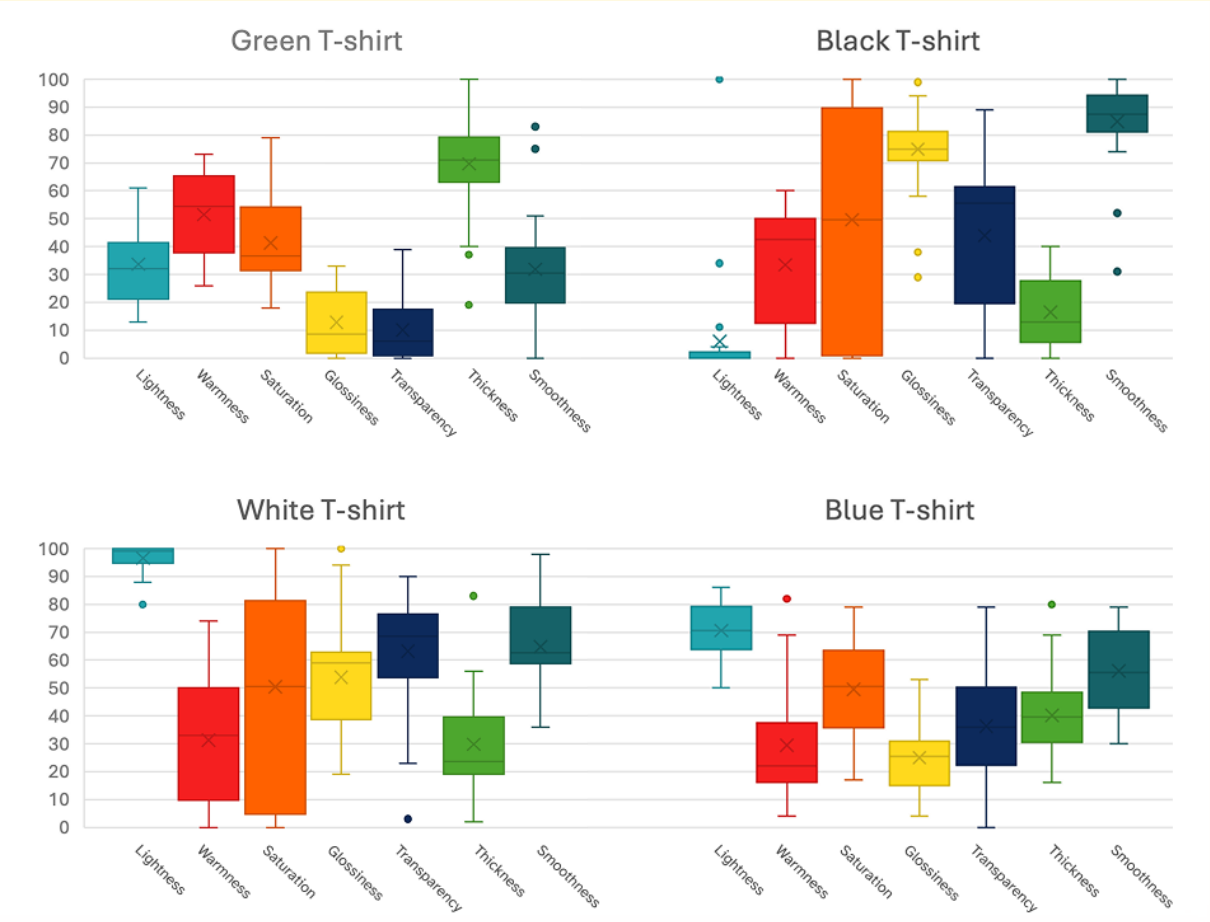


***Figure E.4**. Distribution of in-person baseline ratings for the four garments across the seven measured properties. Ratings were given on 0–100 scales. Each boxplot shows the spread of participant ratings for one property within one garment.*

E.7 Discussion

The baseline ratings provided a workable perceptual reference for the quantitative study. At the same time, some properties showed a greater spread than others, indicating that not all fabric qualities were judged equally consistently in person. This is especially relevant when interpreting the accuracy scores in Chapter 4, since those scores reflect agreement with a mean human baseline rather than with an objective physical ground truth.

For some properties, variability was quite high. In particular, colour saturation showed substantial spread for the white and black T-shirts, making this property less stable or meaningful. The baseline values should therefore be understood as aggregated perceptual references rather than exact physical truths.

Appendix F Quantitative test

F.1 Participants and procedure interface

As described in Section 4.3.2, participants for the online study were recruited from European countries. Table F.1 provides a breakdown of participants by country. Figure F.1 shows the instruction page of the survey that participants completed before being led to the experiment page.

***Table F.1**. Distribution of countries of residence for participants of the online quantitative study.*

Country	*N* (of 61)
Croatia	1
Germany	2
Greece	5
Ireland	1
Italy	4
Latvia	1
Poland	12
Portugal	6
Romania	2
Spain	4
United Kingdom	18

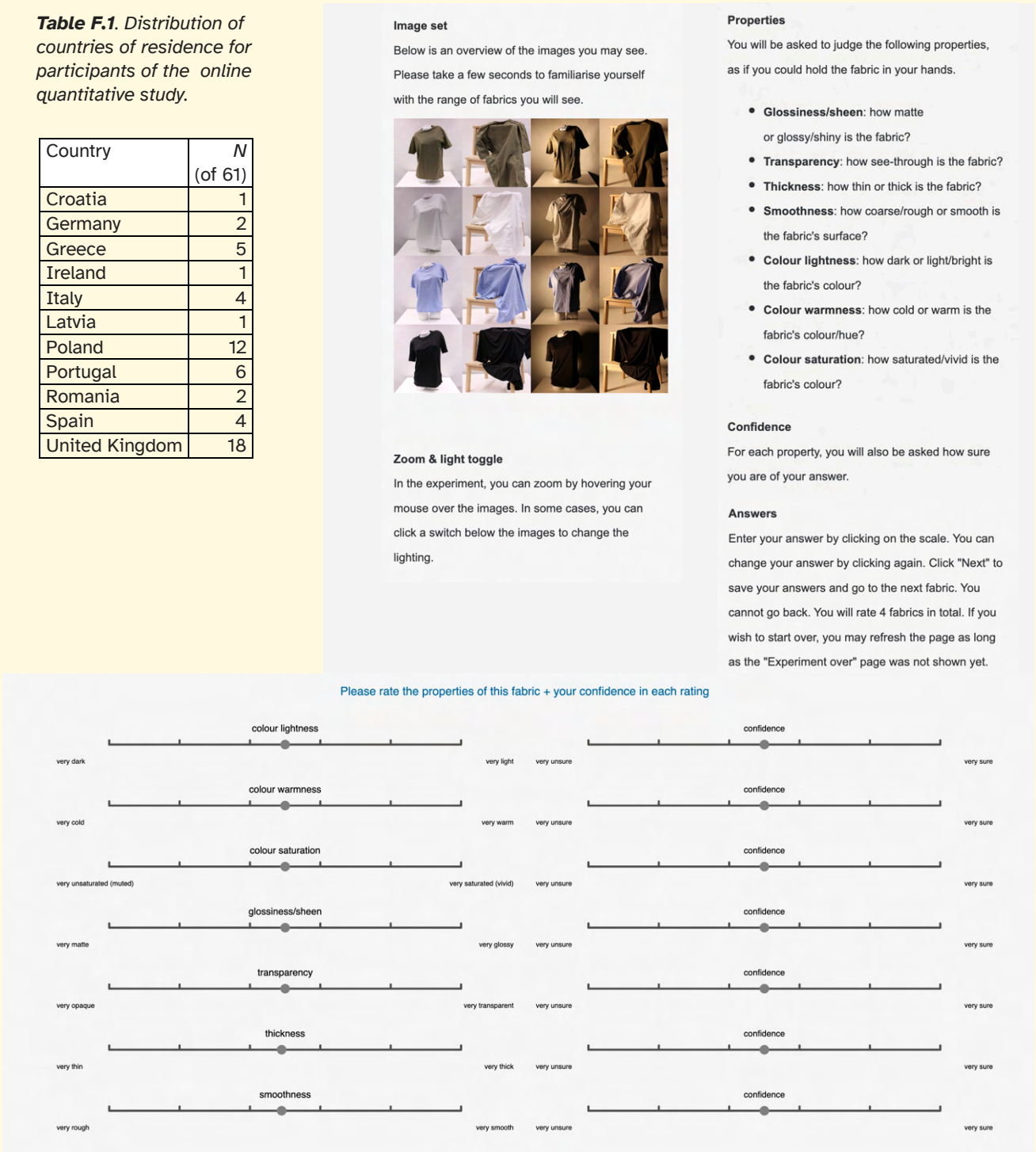


***Figure F.1**. Calibration and instruction page shown to online test participants before being led to the experiment page. This page introduced the range of stimuli, explained the measures, and familiarised participants with the response format and interface.*

F.2 Supplementary results

This Section provides supplementary numerical results for the quantitative study reported in Chapter 4. It includes the full descriptive statistics underlying the graphs in Section 4.4.1, as well as additional tables for the exploratory follow-up analyses described in Section 4.4.5.

F.2.1 Descriptive statistics

The graphs in Section 4.4.1 provide a visual overview of the descriptive results. Table F.2 reports the corresponding mean accuracy and confidence values for each property and lighting condition. These descriptive statistics are based on the full dataset. For inferential analyses requiring balanced independent observations, a reduced dataset was used, as described in Sections 4.4.2 and 4.4.3.

***Table F.2**. Mean accuracy and confidence values. The highest value for each property is shown in bold.*

	Mean Accuracy (0-100)			**Mean Confidence** (0-100)		
Property	Diffuse N = 80	Focus N = 82	Both N = 82	Diffuse N = 80	Focus N = 82	Both N = 82
Overall	81.3 SD = 7.87	**82.1** SD = 6.41	81.8 SD = 6.78	**79.54** SD = 10.6	78.12 SD = 11.3	79.05 SD = 12.2
Glossiness	75.7 SD = 20.5	**82.9** SD = 15.9	81.7 SD = 16.8	**81.76** SD = 14.5	77.61 SD = 17.0	77.09 SD = 18.2
Transparency	77.9 SD = 16.4	**81.7** SD = 15.2	78.9 SD = 15.6	**83.48** SD = 16.5	81.45 SD = 18.0	78.66 SD = 18.9
Thickness	78.7 SD = 17.4	**82.6** SD = 15.6	79.9 SD = 17.6	**77.99** SD = 15.3	75.40 SD = 16.0	76.48 SD = 18.5
Smoothness	82.5 SD = 10.8	81.9 SD = 15.8	**84.7** SD = 12.3	74.28 SD = 16.0	**77.26** SD = 15.4	76.70 SD = 17.1
Colour lightness	**92.4** SD = 8.4	87.4 SD = 11.6	92.0 SD = 8.5	86.96 SD = 14.9	86.24 SD = 13.1	**88.01** SD = 12.4
Colour warmness	**82.9** SD = 12.1	78.8 SD = 12.9	78.0 SD = 13.8	76.01 SD = 17.2	75.72 SD = 18.8	**79.05** SD = 17.4
Colour saturation	79.0 SD = 15.8	**79.1** SD = 13.3	77.4 SD = 16.7	76.28 SD = 16.8	73.13 SD = 19.1	**77.38** SD = 18.7

F.2.2 Exploratory follow-up analyses

This subsection provides the numerical results underlying the exploratory follow-up analyses reported in Section 4.4.5.

Directional bias in property judgments

Table F.3 provides the numerical values underlying the signed-error heatmap shown in Section 4.4.5, including the sample size and standard deviation for each property and lighting condition. Signed error was calculated as the difference between the online rating and the in-person baseline rating on a 100-point scale. Negative values indicate underestimation relative to the baseline, positive values indicate overestimation.

***Table F.3**. Mean signed error by property and lighting condition, including sample size and standard deviation.*

Property	Lighting	N	Mean signed error	SD of signed error
Glossiness	Diffuse	80	-16.60	27.20
	Focus	82	-3.92	23.13
	Both	82	-9.72	22.93
Transparency	Diffuse	80	-15.08	23.05
	Focus	82	-12.56	20.27
	Both	82	-13.53	22.53
Thickness	Diffuse	80	12.14	24.72
	Focus	82	7.14	22.32
	Both	82	12.04	23.88
Smoothness	Diffuse	80	0.39	20.63
	Focus	82	-2.93	23.93
	Both	82	-2.50	19.53
Lightness	Diffuse	80	-0.59	11.36
	Focus	82	-5.46	16.30
	Both	82	-0.13	11.71
Warmness	Diffuse	80	3.62	20.75
	Focus	82	8.80	23.26
	Both	82	8.76	24.60
Saturation	Diffuse	80	-3.44	26.17
	Focus	82	-5.36	24.26
	Both	82	-4.70	27.83

Tendency towards Diffuse or Focus in the Both condition

For each garment × property combination, the absolute distance between the mean Both rating and the mean Diffuse and Focus ratings was calculated. Lower values indicate greater similarity. The final column indicates whether the Both condition was closer to Diffuse or Focus for each garment × property combination.

***Table F.4**. Mean ratings for each condition, and the absolute distances of the Both condition to each single-light condition. The final column indicates whether the Both condition was closer to Diffuse or Focus in each garment × property combination, coloured for clarity.*

Garment	Property	Mean Diffuse	Mean Focus	Mean Both	Distance to Diffuse	Distance to Focus	Both closer to
Black T-shirt	glossiness	32.27	59.55	52.00	19.73	7.55	Focus
	transparency	10.59	15.90	24.05	13.46	8.15	Focus
	thickness	53.27	36.80	48.05	5.22	11.25	Diffuse
	smoothness	72.23	74.30	81.05	8.83	6.75	Focus
	colour lightness	3.27	6.45	3.47	0.20	2.98	Diffuse
	colour warmness	36.59	46.55	36.26	0.33	10.29	Diffuse
	colour saturation	48.32	48.75	45.84	2.48	2.91	Diffuse
White T-shirt	glossiness	30.50	45.25	35.56	5.06	9.69	Diffuse
	transparency	42.00	53.00	47.72	5.72	5.28	Focus
	thickness	38.31	40.20	42.44	4.13	2.24	Focus
	smoothness	68.81	59.60	57.44	11.37	2.16	Focus
	colour lightness	92.31	81.50	94.60	2.29	13.10	Diffuse
	colour warmness	35.81	51.00	39.00	3.19	12.00	Diffuse
	colour saturation	39.00	39.10	40.00	1.00	0.90	Focus
Blue T-shirt	glossiness	25.89	20.94	27.96	2.07	7.02	Diffuse
	transparency	25.39	20.56	23.04	2.35	2.48	Diffuse
	thickness	44.44	50.33	47.52	3.08	2.81	Focus
	smoothness	58.17	39.67	50.64	7.53	10.97	Diffuse
	colour lightness	75.06	64.83	73.44	1.62	8.61	Diffuse
	colour warmness	38.94	38.17	48.88	9.94	10.71	Diffuse
	colour saturation	46.50	36.72	45.20	1.30	8.48	Diffuse
Green T-shirt	glossiness	11.38	22.33	14.31	2.93	8.03	Diffuse
	transparency	12.50	10.67	8.77	3.73	1.90	Focus
	thickness	67.33	60.63	60.62	6.72	0.01	Focus
	smoothness	40.54	47.33	46.38	5.84	0.95	Focus
	colour lightness	30.63	28.71	30.00	0.63	1.29	Diffuse
	colour warmness	50.38	47.50	50.08	0.30	2.58	Diffuse
	colour saturation	40.88	42.71	45.54	4.66	2.83	Focus

Across these 28 combinations, the Both condition was closer to Diffuse in 16 cases and closer to Focus in 12 cases.

Alignment of the Both condition with the more accurate single-light condition

For each garment × property combination, the single-light condition with the higher mean accuracy was identified. The table then indicates whether the mean Both rating was closer to that more accurate condition or to the less accurate one. Negative difference scores indicate closer alignment with the more accurate single-light condition, whereas positive values indicate closer alignment with the less accurate one.

***Table F.5**. Alignment of the Both condition with the more accurate single-light condition for each garment × property combination. The table shows which single-light condition was more accurate (coloured for clarity), which condition the mean Both rating was closer to, and the resulting difference score.*

Garment	Property	Which view was more accurate?	Both closer to	Difference score	Aligned with more accurate?
Black T-shirt	glossiness	Focus	Focus	-12.18	Yes
	transparency	Focus	Focus	-5.31	Yes
	thickness	Focus	Diffuse	6.03	No
	smoothness	Diffuse	Focus	2.07	No
	colour lightness	Diffuse	Diffuse	-2.78	Yes
	colour warmness	Diffuse	Diffuse	-9.96	Yes
	colour saturation	Focus	Diffuse	0.43	No
White T-shirt	glossiness	Focus	Diffuse	4.63	No
	transparency	Focus	Focus	-0.44	Yes
	thickness	Focus	Focus	-1.89	Yes
	smoothness	Focus	Focus	-9.21	Yes
	colour lightness	Diffuse	Diffuse	-10.81	Yes
	colour warmness	Diffuse	Diffuse	-8.81	Yes
	colour saturation	Focus	Focus	-0.10	Yes
Blue T-shirt	glossiness	Focus	Diffuse	4.94	No
	transparency	Diffuse	Diffuse	-0.14	Yes
	thickness	Diffuse	Focus	0.26	No
	smoothness	Diffuse	Diffuse	-3.45	Yes
	colour lightness	Diffuse	Diffuse	-6.99	Yes
	colour warmness	Diffuse	Diffuse	-0.78	Yes
	colour saturation	Diffuse	Diffuse	-7.18	Yes
Green T-shirt	glossiness	Diffuse	Diffuse	-5.09	Yes
	transparency	Focus	Focus	-1.83	Yes
	thickness	Diffuse	Focus	6.71	No
	smoothness	Diffuse	Focus	4.89	No
	colour lightness	Diffuse	Diffuse	-0.67	Yes
	colour warmness	Diffuse	Diffuse	-2.28	Yes
	colour saturation	Diffuse	Focus	1.83	No

Across the 28 combinations, the Both condition was closer to the more accurate single-light condition in 19 cases and to the less accurate condition in 9 cases.

