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Preliminary Study on Haptics of Textile Surfaces via Digital Visual Cues

B. Quattelbaum [1,✉], S. Wolter [1] and K. Stylidis [2,3]

[1] Niederrhein University of Applied Sciences, Germany, [2] University West, Sweden,
[3] Chalmers University of Technology, Sweden

✉ bastian.quattelbaum@hsnr.de

Abstract

Humans perceive through various sensory impressions, including the five senses. Not only the number of different stimuli in everyday life increase, but also the degree of assessment of urgent and irrelevant information. But online it is not possible for the customer to physically perceive and assess the haptics of a product. This paper focus on the questions if it is possible for humans to perceive and identify surface properties without using their sense of touch and if humans can judge and classify the haptics of a textile materials via digital channels through a purely visual perception?

Keywords: digital design, customer integration methods, evaluation, haptics, visual cues

1. Introduction

In everyday life, humans perceive the environment through various sensory impressions, including the classic five senses - sight, hearing, taste, smell and touch. (Gregory, 1987) Even in prehistoric times, the survival of the Stone Age people was determined and secured by the perception of stimuli. It is known that human's previous experiences with artifacts also have a strong influence on their judgments afterwards. According to Krippendorff (2005): "Humans do not see and act on the physical qualities of things, but on what they mean to them." However, due to human evolution, the focus on the perceptible stimuli has changed immensely. Not only the number of different stimuli in everyday life increased, but also the degree of assessment of urgent and irrelevant information. (Younas et al., 2018) In this respect, companies in the 21st century facing with major challenges in terms of customer availability, recognition value, customer satisfaction and long-term customer loyalty. Therefore, the aim of organizations is to draw consumers' attention to products or services via various sensory channels. (Bolton R.N. et al., 2014) When making a purchase decision, consumer in stationary retail or online business are in an inner conflict for or against the purchase of goods. After an individual match of personal expectations and the associated purchase factors like price, discount, brand, sustainability, shipping and payment methods, etc. attention is also paid to the design and quality of a product. (Vasić et. al., 2019) Taking the materials of a product into focus, they are not only judged based on quantitative factors like financial, ecological incentives, but also by the experiences through visual or haptic interaction. Of course, is this experience impacted by the consumer´s age, gender, level of education or cultural background. (Grunwald, 2008)
Due to the key figures of an increasing e-commerce sales, the requirements for companies to use digital channels and media are also increasing to expand and promote more intensively. The presentation of products on the Internet are a decisive criterion for the online purchase of a consumer goods. (Boardman and Mccormick, 2019) On online websites it is not possible for the customer to physically perceive and assess the haptics of a product. Looking at textile products for instance this

leads to high numbers of return shipments. The customer must refer to already memorized experiences and associate them with new situations. (Grunwald, 2008) However, the pressure on companies to act is not only increasing due to the digital age, but also since the global outbreak of the COVID-19 pandemic. One vivid example is the automotive industry. The visual assessment of the vehicle is one of the early and critical aspects for quality perception, including materials quality (e.g., car seats materials). Customer's interpretation of the design is based on the product's visual form, but also on physical interaction with the product (Crilly et al., 2004). Today, when more and more cars sold online, the physical interaction often considered 'a posteriori' action. The reality is that a vehicle's functionality and performance are often taken for granted, shifting consumers' attention to visual appearance of materials (Braun et al., 2020). Studies on sensory dominance confirm that at the moment of purchase, among all our senses, vision is the most important modality. Nowadays, there are only three solutions in digital commerce to present the haptic of products: Images (e.g., detailed product images), videos (e.g. 360-degree views) or sounds (e.g. sound of touching a material). (Vezzetti E. et al., 2019)
In the end, there are two main research questions to answer: Is it possible for humans to perceive and identify textile surface properties without using their sense of touch? (1) Can humans judge and classify the haptics of a textile materials via digital channels through a purely visual perception? (2)
To answer these questions this paper shows an approach to firstly breaks down analogue haptic perception into different general attributes and then secondly investigates if these attributes can be perceived within a digital reality consistent to the analogue perception. The consistency will be checked with statistical measures.

2. Background

Human perception always takes place via the same perceptual processes and can be represented pictorially with the help of a perceptual chain. (see Figure 1) Starting with the physical sensing of stimuli up to reaction. A stimulus from the environment is detected by the receptors of the perceiver's senses through a specific medium and transmitted to the sensory centre in the brain (cortex with associative region). The incoming stimuli are then processed into multimodal, sensory or motor information, whereupon a response is triggered. (Sathian, 2016) The sensory organs of haptic and visual perception are the skin and the eyes.

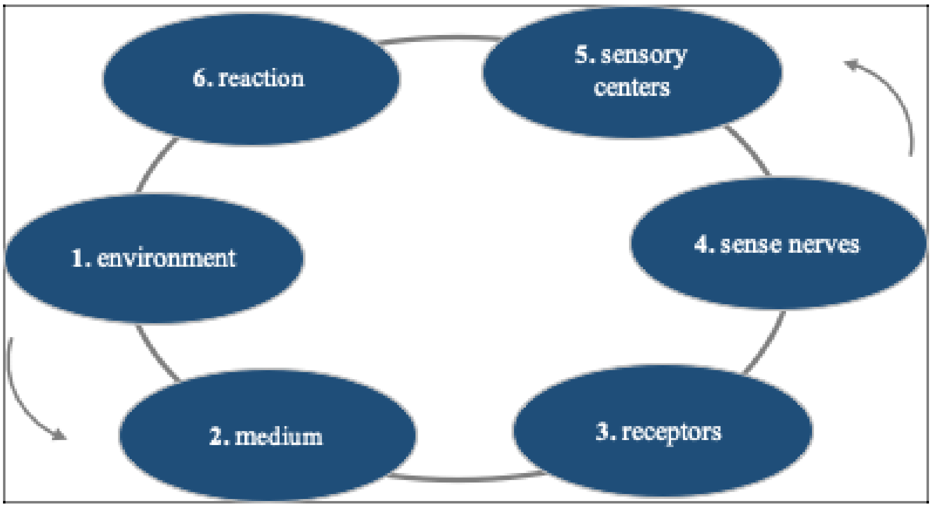

Figure 1. Perceptual chain

The consumer receives information about the material, texture, weight, or consistency of a product through the active form of perception: haptics. Conscious sensations are realized by a customer by stroking, pressing or grasping the product in stationary retail. Product design can therefore convey emotional impressions of a brand or product to the buyer. (Klatzky & Lederman, 1992). Moreover, at the moment of spotting a product or material, an initial response in the form of 'like or dislike' or

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‘approach or avoid’ can be formed within the blink of an eye (Hekkert, 2014). These types of opinions can be formed even before interacting with the product.

Nevertheless, there is an assumption that only a few marketing managers deal with the haptic effect as a strategic marketing tool and consciously integrate in their marketing mix. However, it can be statistically proven that companies that include haptic details in marketing strategy benefit from them and are more successful. As a side effect, parallel haptic campaigns, products and sales processes control against the loss of efficiency of advertising, increasing interchangeability and decreasing credibility of brands. (Müller et al, 2011)

Customers’ attitude and feelings toward a product change when they are not able to experience the product haptically. Touching a product leads to an increase in consumers’ psychological ownership and to a higher valuation of product. (Peck and Shu, 2009) Some product categories like clothes and fresh produce, have a higher touch diagnosticity compared to products such as technical devices and books, which do not require as much physical inspection. (Kühn et al., 2020).

The study "How touch feeds taste in online produce retailing" underlines this opinion, because the results show that consumers prefer to inspect kiwis, apples, and tomatoes haptically before purchasing them in a grocery store. (Kühn, 2021) The same touch feeling is important when customers buy a magazine, because they want to feel the smooth, silky surface of an ad in a magazine, no doubt, generates an emotional bond with the advertised brand. (Rupini and Nandagopal, 2015) Everyday customers use touch surfaces which are an integral part of our mobile phones, smart watches, tablets, laptops, and electronic kiosks in the digital world. In this context the active haptic is also an important fact for the customer experience. (Basdogan et al, 2020)

While customer's experience with materials is always multisensory, different sensory modalities have differing contribution to this experience. According to Fenko et al. (2010) the overall dominance of vision over touch has been demonstrated in many studies including determination of shape, size, length, curvature, depth, and spatial location. However, when participants were given the task to evaluate surfaces regarding their roughness, haptic sensations were prevalent comparing to visual cues (Lederman et al., 1986). Speaking of product experience visual domain also prevails in assessment of consumer products (Schifferstein and Cleiren, 2005). Another study focusing on the role of sensory modalities in product perception (Schifferstein and Desmet, 2007) found that vision collects the most information about the product in the shortest possible time. Rakhin and Onkar (2018) did first analysis to compare the perception of textiles for a physical object with its visual representation. They showed for one attribute (smooth - rough) which were derived out of the theory that there is strong correlation between the analogue and digital reality. These findings naturally create space for further investigation on common consumer-oriented attributes reflected in this study.

3. Methodology

In a physical haptic study various materials were presented to the participants in a standardized manner using standardized mock-ups, with the purpose to eliminate the visual sense. From the beginning the test person should imagine that they have their shopping experience in a stationary retail store and assess the product provided according to their personal ideas. (see Fig 2)

In a first step all presented material samples get evaluated individually by all test persons according to their personal criteria. They do interact with the materials using only the sense of touch. Their experience is verbalized by "thinking-out-loud" and recorded by an instructor. During a subsequent discussion involving all participants clear definitions of the haptic material attributes associated with a common description including delimitation terms are derived. Thirdly, test instructions for each attribute get elaborated to enable a better transfer for the later digital study. Finally, the participants come back to the physical material samples - again just by touching - to apply their own defined attributes and instructions. This step offers a scaling of the different fabrics haptically. The general scale itself is built up from 1 to 10, so that a tendency of the sensation is clear and can be evaluated. The margin of a scale is represented by the delimitation terms. The results of that last step are mandatory in order to make an adequate comparison of the perception in the real and digital representation. (Figure 2)

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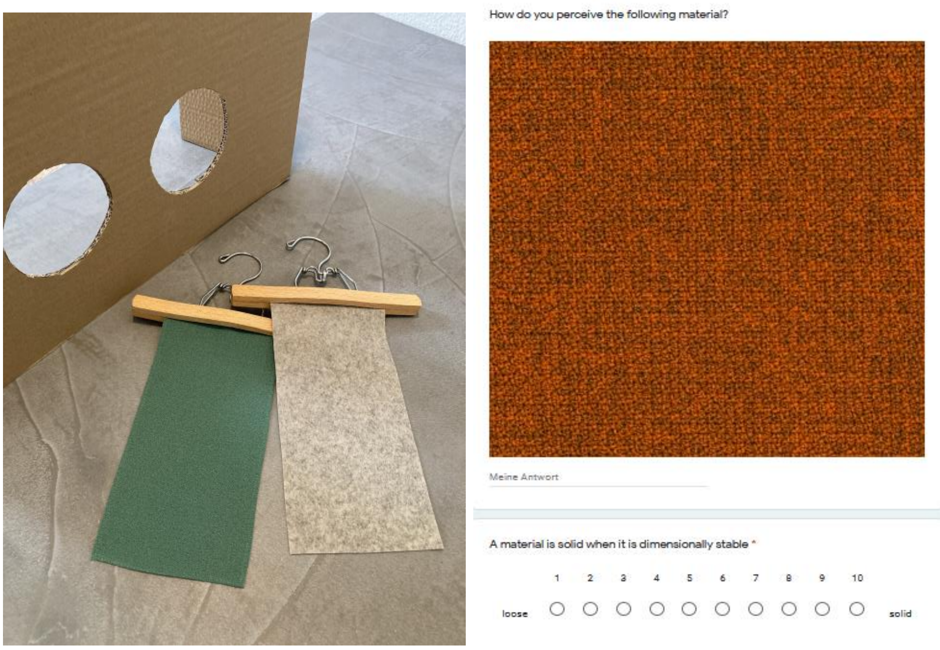

Figure 2. material presentation (left), survey digital study (right)

The digital study is built up and derived from the findings of the haptic study. At the beginning, each participant is given a short introduction, in which the background of the research study is explained, and a short initial situation is described. Again, the participants are asked to imagine to be in a stationary store of their choice and test the materials according to the given test instructions. To present the materials high resolution pictures (1181 x 1181 pixel) were taken. So, the participants have the chance to zoom-in and to have a close-up of the texture by their individual decision. With the aim to be as close as possible to real scenarios, every participant was left free to decided which technical set-up to use or how to apply the digital study. Each picture is described by the details derived from the findings of the haptic study. The attributes, the descriptions, the test instructions, and the scales of all material samples are identical to the haptic study. The assessment in the digital study is carried out purely by visual perception of the haptic material properties. At the end socio-demographic information gets recorded. To derive conclusion whether the digital study delivers comparable results to the physical haptic study statistical methods such as Pearson correlation or mean value comparison (t-test) incl. Levene-test (see Sachs, 2012) are performed. (see Figure 3)

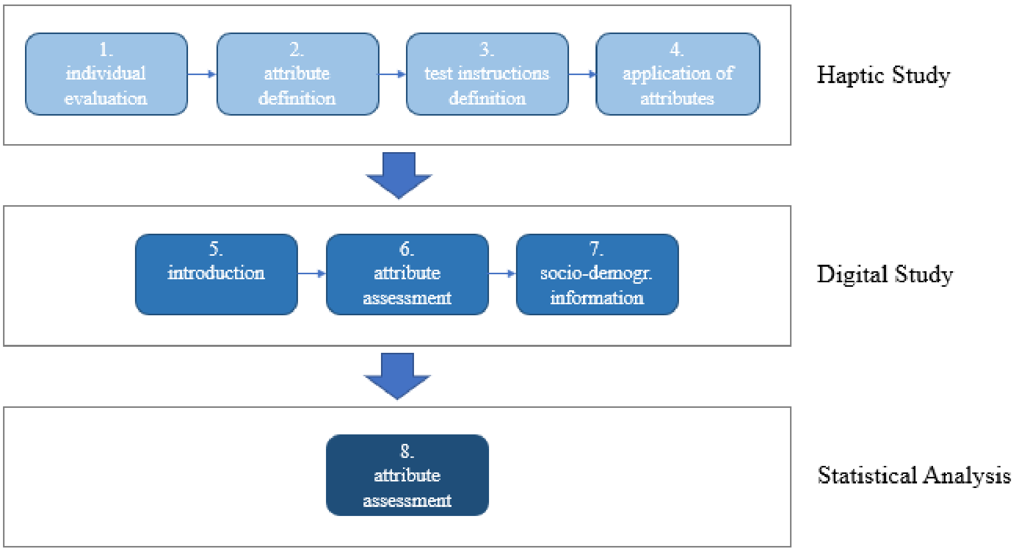

Figure 3. Methodology study overview

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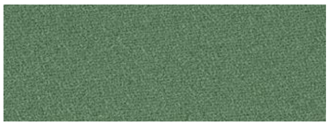
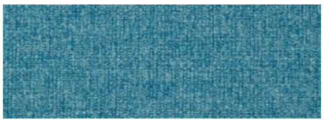
4. Results

As the methodology showed the study approach was divided into two sections. In the following both sections' results will be presented individually.

Haptic Study:

During the haptic study ten participants assessed 14 different materials (see Table 1). The participants represented different ages ranging from 18 to 50+ and gender groups (female: 7/ male: 3). The 14 materials were provided by the company Gabriel GmbH and contained different base materials. (see Table 1) Observing the participants, it could be noticed that all samples were examined in a similar way with both hands. Almost everyone rubs the top of the fabric with their thumbs and the bottom with their index and middle fingers. To perceive the stretchability or elasticity of the sample the material is pulled in both transverse and longitudinal directions. The participants determine the haptic perception of the samples mostly with the following statements: "The fabric/material/surface feels like...", "I perceive the fabric as..." or "I would use this material as...". Often people imagine qualitative features of a piece of textile in which it is thought that a material could possibly be "breathable" or "water-repellent". Woolly materials are often referred to as "hairy" or "uncomfortable on the skin" because they are perceived as very scratchy. Through a roughened surface, some participants also associate mechanical material equipment or chemical treatment through a soapy surface. In this context, various trade names of substances are also uttered, such as "neoprene", "microfiber", etc. Some participants classify the materials without being challenged, in that the material is perceived as “very firm” or “very soft”.

Table 1. Overview materials

1		6		11	
2		7		12	
3		8		13	
4		9		14	
5		10			

Based on all individual experiences the participants together defined eight fixed generic attributes for the haptic description of textile materials. All uttered adjectives are assigned to the respective nouns 1 to 8, so that the core attributes are representative of all verbalized utterances (e.g. Figure 4):
Strength (solid), Wool (woolly), Softness (soft), Felt (felty), Structure (structured), Ease (easy), Elasticity (elastic), Smoothness (smooth).

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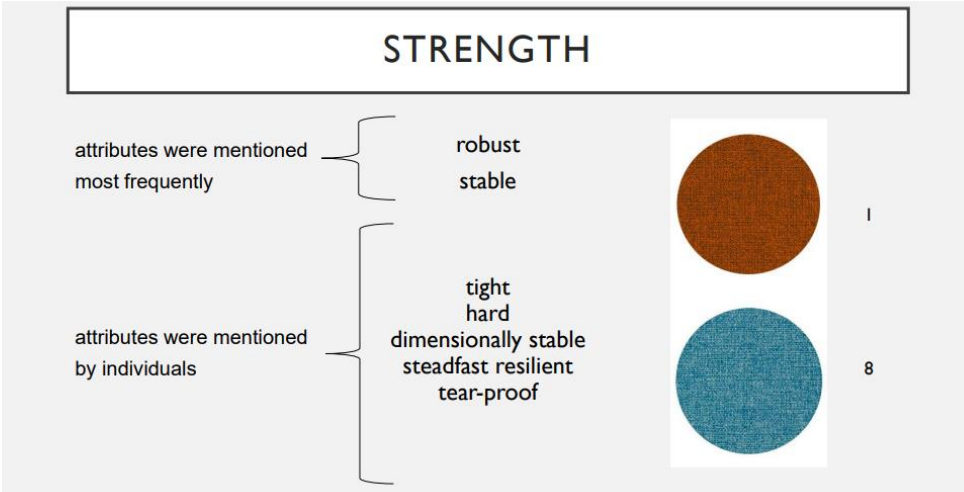

Figure 4. Perception attribute example

In addition, all attributes are described by a short definition so that they can be used as a brief explanation of terms for the participants in following digital study:

- A material is solid when it is dimensionally stable.
- A material is woolly if it keeps you warm.
- A material is soft when it is pliable on the skin.
- A material is felty when it is hairy.
- A material is structured when the surface is uneven.
- A material is ease when it is light.
- A material is elastic when it can be stretched in all directions.
- A material is smooth when no structure can be felt.

As a last task of the haptic study the participants were asked to apply their own attribute definitions on the given materials and classify/objectify the materials. The given Likert scale of ten was widely applied with a tendency to not apply the outer margins. Even though only ten participants participate in the haptic study we performed a correlation analysis for the different attributes. (see Table 2) It can be seen that "wool" and "felt" as well as "structure" and "smoothness" do have a strong correlation. Therefore, they may focus on the same characteristic experience of the participants.

Table 2. Significant correlation in the haptic study

variables	r *
wool – strength	-0,227
softness – strength	-0,412
felt – strength	-0,274
felt – wool	+0,781
structure – softness	-0,437
ease – wool	-0,322
ease – felt	-0,401
elasticity – strength	-0,349
smoothness – softness	-0,439
smoothness – structure	-0,764

*the two-sided significance value for the variables listed is between 0.0% and 0.7% (<1.0%).

Visual Study:

All 14 materials were presented in the visual study to 82 participants ranging age-wise from 18 to 50+ and representing a gender split of female: 51; male: 30 and divers: 1.

For a better understanding of the perceivability of the materials represented with visual cues only, we take a detailed look on the Likert scale results. The mean values for all samples of the attributes are on

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a scale between 5.10 and 6.35 compared to 3.05 to 8.00 in the haptic study. These values may indicate that the participants judgement of the various characteristics is more difficult visually via a digital medium. If we take the attributes "strength" ($\bar{x}$ = 6.87) and "elasticity" ($\bar{x}$ = 5.10) into consideration, only a weak dependence of the variables can be mapped overall. With a more detailed view on the second sample, however, it becomes clear that this fabric sample also offers low elasticity due to its high strength.

Analogous to the haptic study a correlation analysis of the attributes was performed. In the digital study, the two-sided significance value for the variables listed in the following Table 3 is between 0.0% and 0.9% (<1.0%).

Table 3. Significant correlation in the digital study

variables	***r***
wool – strength	+0,209
softness – strength	-0,326
softness - wool	-0,112
felt – strength	+0,191
felt – wool	+0,764
structure – strength	+0,136
structure – wool	+0,372
structure – softness	-0,146
structure – felt	+0,354
ease – strength	-0,300
ease – wool	-0,240
ease – softness	+0,534
ease – felt	-0,178
ease – structure	-0,268
elasticity – strength	-0,382
elasticity – softness	+0,469
elasticity – felt	-0,078
elasticity – ease	+0,538
smoothness – wool	-0,230
smoothness – softness	+0,343
smoothness – felt	-0,190
smoothness – structure	-0,590
smoothness – ease	+0,539
smoothness – elasticity	+0,293

As in the haptic study the correlation between "wool" and "felt" can be classified as strong. But different to the haptic study the attributes "structure" and "smoothness" only show a medium correlation similar to "ease/softness" or "smoothness/ease".

To investigate the research question if participants can perceive haptics of materials with purely applying the visual sense a mean value comparison of the two studies is carried out using the t-test with independent random samples. The mean values of the variables from two independent groups are analysed in more detail here. The case groups of the haptic and digital study can thus be viewed separately from one another. It must be checked whether the mean values in the population are different.

For the t-test the following two hypotheses were defined:

H_0 (null hypothesis): The haptic and digital sample are identical in the population.

H_1 (alternative hypothesis): The haptic and digital sample are not identical in the population.

In parallel, the Levene test was applied to check the homogeneity of variance in the groups. The resulting f-value is necessary because the group sizes of the two samples are different.

It can thus be seen from Table 4 that if the significance of the Levene test has a value less than 0.05, the variances are consequently not equal. For variables with a significance greater than 0.05, however,

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the variances are the same. The attributes "wool", "softness", "felt" and "smoothness" of both samples do not represent a significant relationship. The null hypothesis must therefore not be rejected. These findings show that the perception of these attributes by the participants in the haptic and digital study is identical. The alternative hypothesis is therefore rejected. The characteristics of "strength", "structure", "ease" and "elasticity", on the other hand, are highly significant to significant, which means that the null hypothesis can be rejected. The alternative hypothesis is thus accepted. The participants of the haptic and digital study cannot perceive these variables identically.

Table 4. Interpretation t-test for independent samples

	Levene	t-Test
variable	significance	sig. (2.-side)
strength	0,000	0,000
wool	0,004	0,103
softness	0,555	0,053
felt	0,035	0,125
structure	0,433	0,000
ease	0,370	0,023
elasticity	0,000	0,000
smoothness	0,159	0,587

In conclusion, however, it should be mentioned that the t-test only compares the mean values of both samples and the results do not prove that an observer cannot fundamentally perceive the variables digitally.

5. Discussion and Outlook

In the present paper, the perception and assessment of the haptics of textile surfaces via digital channels should be examined in more detail and the research questions posed thereby should be answered.

The implementation of the haptic and digital study proves that it is possible for customers to perceive various haptic attributes on a material surface using a digital medium. Basically, it is therefore possible for humans to perceive and identify surface properties without using their sense of touch. The degree of perception can, however, vary depending on the material properties or characteristics. The clarity of the perception performance also depends on other factors such as age, gender, and textile experience.

The findings provide companies with great potential in expanding the digital world, with a particular focus on the psychological perception of products. Haptic stimuli can be used consciously in online shops. The lack of contact could thus visually compensate for the sensations using adequate product representations. Marketing campaigns can therefore increase product presence through the haptic effect and increase customer awareness.

Evaluation of materials' quality is a process that includes many aspects of human cognition and properties of the material, including emotion, aesthetic, and design perception. However, there is often a clear gap between the intentions of the designer and the expectations of customers about the material's behaviour. In fact, designers often have incomplete information about the sensory perception of qualitative characteristics perceived by the consumer (Stylidis et al., 2020). Designers often use an intuitive approach to translate the voice of customer into technical requirements, primarily because of the subjective nature of some design attributes and a lack of robust methods for capturing and quantifying customer's quality impression (Eckert et al., 2014). Customers, in turn, often find it difficult to get a meaningful idea of a product with a high degree of complexity, e.g., composite car seat in a premium car market segment. Often, the customer's perceptions contradict with the image of the brand. The study on customers and experts regarding visual inspection of 30 product components was performed by Baudet, et al. (2013). Their findings spotted an asymmetrical information between what companies think about their product's quality and how the customers

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perceive them. The ability to evaluate material properties just by looking at them becomes extremely important in the new product development and design activities. In the automotive industry production systems are highly complex, with a car itself being a system of systems embedded in a digital environment (Stylidis et.al, 2019). This opens new opportunities for the use of images representing reality. Recently, artificial intelligence (AI) related research boosted due to rapid development of deep learning systems, i.e., systems using neural networks (NN) that mimics the way human brain operates. Machine learning (ML) algorithms have been applied on a variety of applications from voice recognition systems, automotive industry to banking services. A discovery of latent patterns is a key feature of deep learning. A well-known example of the neural network trained to recognize and classify images of dogs and cats. In 2015, the accuracy of neural networks in image recognition identifying has surpassed human ability to do so (He et al., 2016). Two major views on ML exist among designers today - one is to see ML as an actor, and another where ML is a design material (As and Basu, 2021). The designers who imply a pragmatic approach seeing ML as a new form of design material follow the long tradition of developing new knowledge by empirical approach and mixed methods including new and old paradigms. Therefore, there is a distinct possibility to apply supervised ML not only to visual attributes but also to haptic experience.

The conducted study not only points to a relevant research area, but also offers further fields of investigation, from which further conclusions and dependencies between the haptic properties can arise in the future. In a follow-up study, further materials or haptic features should also be used and analysed so that further material characters can be examined via a digital medium. Beside using pictures as visual cues 3D or 4D simulations of materials need to be investigated. The use of these simulations would offer a huge potential in reducing physical samples as well as in shortening the sampling process in total. It can be assumed that pictorial representations of textile product surfaces can basically be assessed purely visually in 3D and 4D applications. At the same time, when using AR or VR devices, it will be important to guarantee users high-quality image quality so that the perceived information from the user interaction achieves the required experience based on the desired expectation. As a result, haptic quality parameters can also be checked optically depending on the criterion and customer satisfaction can be ensured accordingly. The use of haptic stimuli in multi-sensory designs can thus also be mapped via online shops and perceived by the consumer. A future consideration for online product design would be that the more difficult to perceive attributes could be further simulated - e.g., elasticity as pulling a garment apart with both hands -to make the consumers' purchase decision easier. At the same time, in the case of a digitally displayed product, reference could be made to additional information about haptic features of the textile surface.

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