An investigation of the perceived tactile properties using fabric images, videos, and real fabrics

Qinyuan Li[1, †], Kaida Xiao[1, *,†], Ningtao Mao[1, †]

[1] *University of Leeds, LS2 9 JT, Leeds, United Kingdom*

Abstract

The tactile properties of fabrics convey vital information and influence customer decision and satisfaction. The understanding of the tactile properties is not comprehensive due to the multiple tactile properties and the various ways of assessing them. Here, we designed a series of psychophysical experiments to evaluate the multiple tactile properties, including flexible-stiff, smooth-rough, soft-firm, spongy-crisp, warm-cool, using flat fabric images, draped fabric images, rotating fabric videos, and real fabrics that only touch is allowed, only vision is allowed, both touch and vision are allowed. Our results show that it is necessary to study the different tactile properties rather than treat it as a whole. The tactile perception remained consistent yet slightly different among images, videos, and real fabrics, except for warm-cool. Overall, flexible-stiff, smooth-rough, soft-firm, and spongy-crisp perceived from draped fabric images are highly correlated with those perceived from fabric rotation video. Additionally, above mentioned tactile properties perceived from both draped fabric images and fabric rotation videos are more closely related to those perceived through actual observation and touch, compared to those perceived from flat fabric images. By comparing the experiment conditions, we found that in the absence of either vision or touch, consistent perception of the tactile properties can still be obtained using real fabrics. We also found the presence or absence of colour affects the perceived tactile properties only when other visual traits can be observed.

Keywords

Visual tactile properties, fabric images, videos, correlation

1. Introduction

The tactile properties of fabrics are of vital importance in the field of textiles, affecting the purchase by customers and their overall satisfaction with the products they purchase [1]. When buying online, it is one thing to be able to see a fabric on a display, but the visual impression of the tactile response is an important influence on a customer's decision to make a purchase.

Conventional methods to define the tactile properties of fabrics rely on instruments or other devices. For example, the Kawabata Evaluation System for Fabric (KES-F system) and Fabric Assurance by Simple Testing (FAST system) measure the mechanical and thermal properties of the fabrics [2], and the Leeds University Fabric Handle Evaluation System (LUFHES) measures the energy consumed during the fabric deformation [3]. The measured data are calculated to give scores to represent the tactile properties. Devices such as tactile sensors give signals reproducing human movement when touching the surface, which enhances the understanding

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* Corresponding author.

† These authors contributed equally.

cm18ql@leeds.ac.uk (Q. Li); k.xiao1@leeds.ac.uk (K. Xiao); n.mao@leeds.ac.uk (N. Mao)

0009-0008-1730-527X (Q. Li); 0000-0001-7197-7159 (K. Xiao); 0000-0003-1203-9773 (N. Mao)

of the tactile properties and benefits the development of robots [4,5]. However, the notable limitations of such instruments are that they are not available to the public, and the generated data are difficult for consumers to interpret. Furthermore, such objective measurement results cannot represent the subjective human perception of the tactile properties when either fabric images or real fabrics are available.

Apart from the above, psychophysical experiments were conducted to study the subjective human perception of the tactile properties. In virtually all experiments, observers were presented either with the real fabric [6-8] or fabric images and videos [6,9] or both [6,10] under the corresponding conditions (vision, touch, or both). With a few notable exceptions, these studies generally evaluated the perceived tactile properties using a single format of the fabric. The exceptions include a study [6] that conducted three separate experiments to evaluate the tactile perception using fabric images and videos by the means of rating scale; using real fabrics when one touched the fabric and the other observed the fabric and the process; using both by the means of match-to-sample task. It concluded that videos performed better in conveying how the fabrics feel than images. Study that investigated the correspondence between the visual and haptic perception of roughness, and so on, used the method of rating scale, which showed high correlations between visual and haptic modalities [7]. Drewing et al. [11] evaluated softness of rubber under haptic-only, vision-only, and visuo-haptic conditions separately by the means of magnitude estimation and claimed that the perceived softness was significantly different. Overall, the methods and fabric formats used in the previous studies were mixed, and none considered all the fabric formats and used a consistent method. It remains unknown whether the perceived tactile properties are correlated when using images and videos, real fabrics, or both at the same time. One aim of the present study is to build a comprehensive understanding of the fabric tactile perception using fabric images, videos, real fabrics under the different conditions (touch-only, vision-only, vision+touch) and evaluate their correlations.

More importantly, different tactile properties were evaluated individually or collectively in the previous studies. Guest et al. [12] developed a Touch Perception Task (TPT) containing 26 adjectives by asking observers to rate how much the word related to the sense of touch, including warm, cool, soft, rough, smooth, firm, et al. A study that reviewed the tactile perception assessments claimed the most important fabric handle descriptors listed by five organizations for knitted fabrics, including smooth-rough, cool-warm, stretch-tight, soft-harsh, resilient-non-recovery et al. [13], while stiffness, smoothness, and softness were identified as the most important components to describe the fabric hand in the study developing a weighted overall fabric hand value (PH) [14]. A good correlation has been found between the perceived stiffness, softness, force of compression, tensile stretch and the measurement results by FAST [15], and crispness, flexibility, sponginess, stiffness, stretchability, firmness, roughness, and smoothness were capable of being evaluated and calculated using LUFHES [3]. Notably, even though there are different tactile properties studied in previous work, there is similarity and overlap among them. For example, stiffness and smoothness were studies in [9,14,15], and their antonyms flexibility and roughness were studied in [3,7,13]. Nevertheless, none considered all the possible tactile properties at the same time. It is not known whether the perceived different tactile properties remain consistent under varying conditions (images, videos, real fabrics). Table 1 lists different tactile properties evaluated in previous studies.

The objectives of the present study are to investigate the different tactile properties perceived in various conditions of fabric (images, videos, real fabrics that only allow touch, only allow vision, and allow both), and the correlation of these different tactile properties across different conditions. We captured images of the fabrics in both flat and draped states, and videos of the fabrics in draped and rotating state and performed colour characterization on them. Six psychophysical experiments were designed to collect the subjective data of the perceived tactile properties under different conditions, by means of categorical judgement. A detailed correlation analysis was conducted to achieve the objectives.

2. Methodology

2.1. Fabric samples

2.1.1. Real fabrics

A set of 118 fabrics, including but not limited to merino, woollen wool, worsted wool, melton wool, viscose, linen, polyester, silk and organic cotton, was selected for the experiment. The size of each fabric sample was 30 x 30 cm. The fabric density was measured in grams per square meter (gsm), ranging between 69 and 700 gsm. The fabric colours were measured by CM-700d spectrophotometer, setting to MAV, D65 light source and CIE 10 degree observer. Figure 1 shows the reasonable distribution of fabric colours in CIE a*b* and C*L* coordinates. A total of 48 fabrics are semi-transparent, meaning that objects, e.g. palm, placed behind them can still be observed. These fabrics were used in the actual touch and observation experiments described in section 2.2.2.

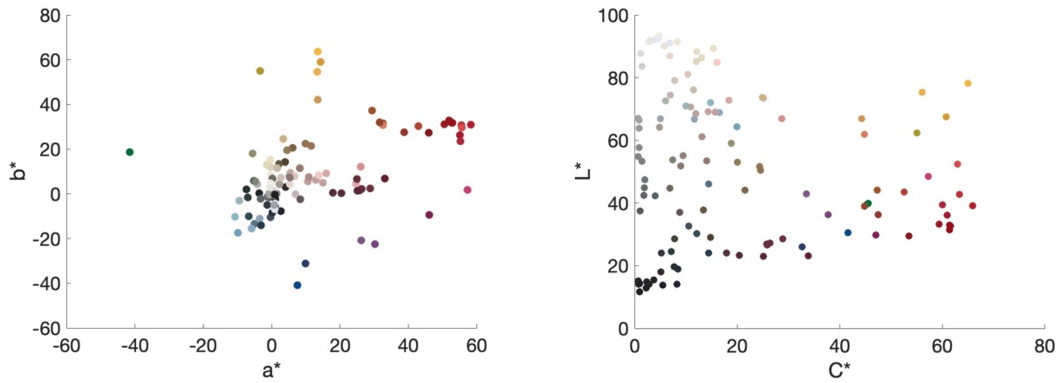

Figure 1: The distribution of fabric colour in CIE a*b* (left) and CIE C*L* coordinates (right).

Table 1
Summary of the tactile scales/descriptors in previous studies

Tactile scales/descriptors	Methods
Tensile and shear, pure bending, compression, surface characteristics (fabric surface profile and coefficient of friction)	The Kawabata Evaluation System for Fabric (KES-F) [2].
Compression, bending, extension, dimensional stability	Fabric Assurance by Simple Testing (FAST) [2].
Crispness, flexibility, sponginess, stiffness, stretchability, firmness, roughness, smoothness	Leeds University Fabric Handle Evaluation System (LUFHES) [3].
Warm, cool, soft, rough, smooth, firm, et al	Touch perception task (TPT) [12].
Smooth, soft, homogeneous, geometric variation, random, repeating, regular, colour variation, strong, complicated	Verbal description of the texture of the textiles [8].
Smooth-rough, cool-warm, stretch-tight, soft-harsh, resilient-non-recovery, et al.	Listed as the most important fabric handle descriptors for next-to-skin knitted fabrics by five organization [13].
Stiffness, density of fabrics	Measured how well observers can perceive the stiffness and density of fabrics from videos and images [9].
Stiffness, softness, force of compression, tensile stretch	The perceived touch traits correlated good with the FAST measurement [15].
Stiffness, smoothness, softness	The first three most important components to describe the fabric hand [14].
Roughness, friction, 3-dimentionality, hardness, elasticity	The first and second principal components for visual modality and haptic modality [7].
No scale used.	match-to-sample task [6,10]

2.1.2. Fabric images and videos

Images of flat and draped fabrics and videos of rotating fabrics were used as parts of the visual stimuli. The fabric was positioned in a flat condition at a 30-degree angle within the X-Rite Virtual Lighting Booth (VLB), illuminated under the simulated CIE D65 lighting condition. There was no other lighting in the room where the photography took place. A Sony DSLR camera with a speed of 1/8 second, ISO 2000, and white balance of 6200K was used to capture images of the flat fabrics, as shown in Figure 2 (A). The VLB provided a rotation stage with adjustable rotational speed, where the fabric was draped freely over a cylindrical stand with a height of 30 cm. The rotation stage was adjusted to rotate clockwise at approximately 270 degree per minute, and the same Sony camera was used to capture the video in manual mode, as shown in Figure 2 (B). The warp direction of the fabric was always at the left side at the beginning of the video. The fabric completed a 360-degree rotation in each video, with a duration of approximately 80 seconds and a framerate of 25. It is noted that the shadows and highlights caused by creases can be different when observed from different angles, leading to different fabric appearances (see Figure 4). Additionally, it is not feasible to maintain the fabric's drape condition completely consistent through repeated draping.Therefore, three frames were extracted from each video at specific points to be used as the fabric draped images: at the start of the video (drape_0), when the fabric rotated clockwise by 45 degrees (drape_45), and when the fabric rotated clockwise by 90 degrees (drape_90). The schematic representation is shown in Figure 3.

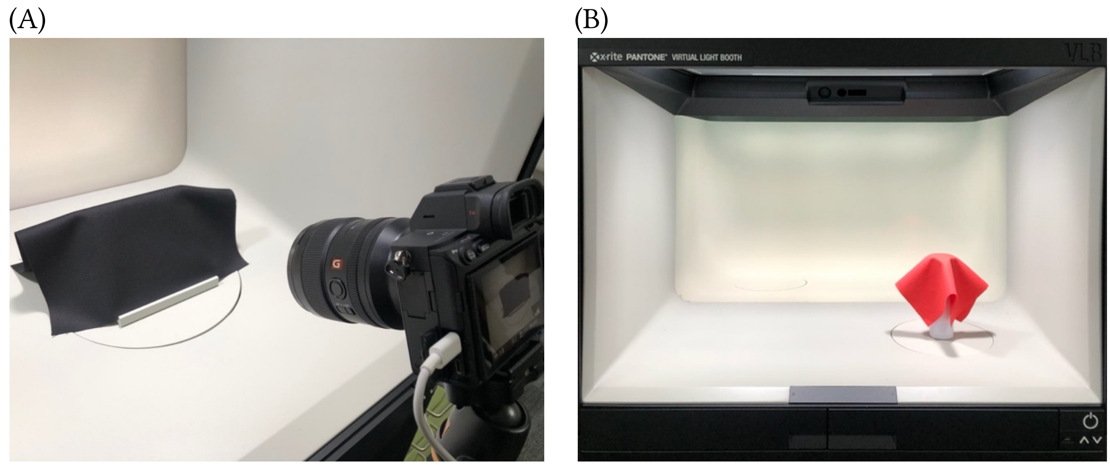

Figure 2: (A) The schematic diagram of capturing the flat fabric images. (B) The schematic diagram of the draped fabric on the rotation stage. The camera stood at the front of the fabric with the distance of approximately 40 cm.

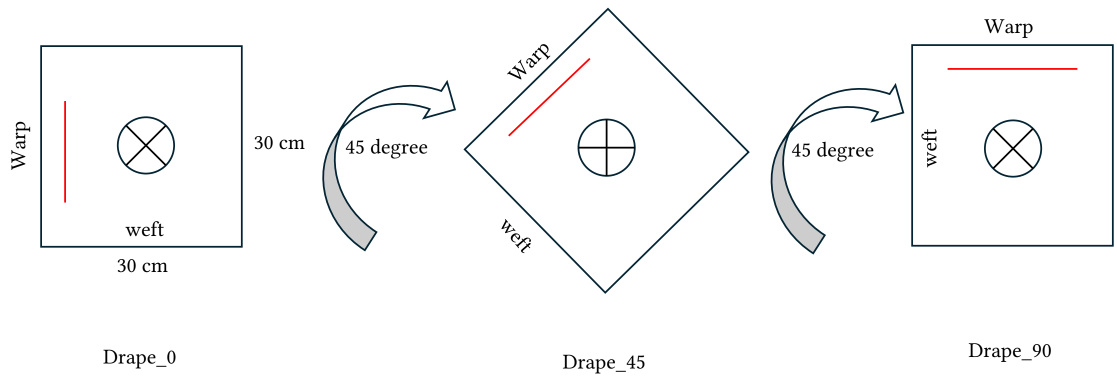

Figure 3: The top view schematic representation of the rotating fabrics. Left: at the start of the video. Middle: when the fabric rotated clockwise by 45-degree. Right: when the fabric rotated clockwise by 90-degree.

2.1.3. Colour management of fabric images and videos

To truly reproduce the appearance of the fabrics, we conducted both camera and display characterization. The GretagMacbeth ColorChecker® DC chart was captured at the same position as the fabrics, using the same Sony camera with the same settings, as the training colour charts for camera characterization. The spectral reflectance of each colour patch was measured using the CM-700d spectrophotometer, and the corresponding CIE XYZ tristimulus values were calculated with the CIE1931 CMFs and the measured SPD of the illumination. Moreover, the camera RGB values of each colour patch were derived from the captured DC chart image. The technique of third-order polynomial regression was used as the mapping method to train an optimized mapping between the input (camera RGB values) and the output (CIE XYZ tristimulus values) [16]. The model achieved the prediction of less than 3.0 ΔE^*_{00} unit averaged from the 240 DC colour patches as test colours. The RGB data of each pixel of each fabric image and video were first transformed to CIE XYZ tristimulus values.

A BenQ professional display was well calibrated at a luminance level of about 114 cd/m^2. The display characterization was implemented using the GOG model [17], trained by conducting transformation between the RGB values of a set of grey scale patches (0:15:255) and the CIE XYZ tristimulus values. The developed GOG model achieved a prediction of less than 0.2 ΔE^*_{00} unit averaged from the 18 neural grey patches as test colours, and less than 0.8 ΔE^*_{00} unit averaged from 30 randomly selected colour patches as test colours. The CIE XYZ tristimulus value of each pixel of the fabric images and videos, transformed through the camera characterization model, was then transformed to the display RGB values through the GOG model and displayed on the BenQ display.

The flat fabric images, draped fabric images, and fabric rotating videos calibrated through the camera and display characterization models were used in the visual-tactile perception experiments described in section 2.2.2. Figure 4 shows the examples of the flat and the corresponding draped fabric images.

2.2. Fabric visual and tactile perception evaluation

2.2.1. Tactile properties

Both instrumental and psychophysical aspects were considered in the determination of the tactile properties in this study. Table 1 lists the tactile properties used in previous studies. Ten popular descriptors of the tactile properties, soft, smooth, rough, firm, warm, cool, spongy, crisp, flexible and stiff, can be directly or potentially derived from Table 1. Based on their definitions in the widely used Oxford online dictionary [18], for example, the explanation of “stiff” is “rigid; not flexible or pliant” [19], the ten descriptors were divided into five pairs of scales that had opposite meanings: flexible-stiff, smooth-rough, soft-firm, spongy-crisp, warm-cool.

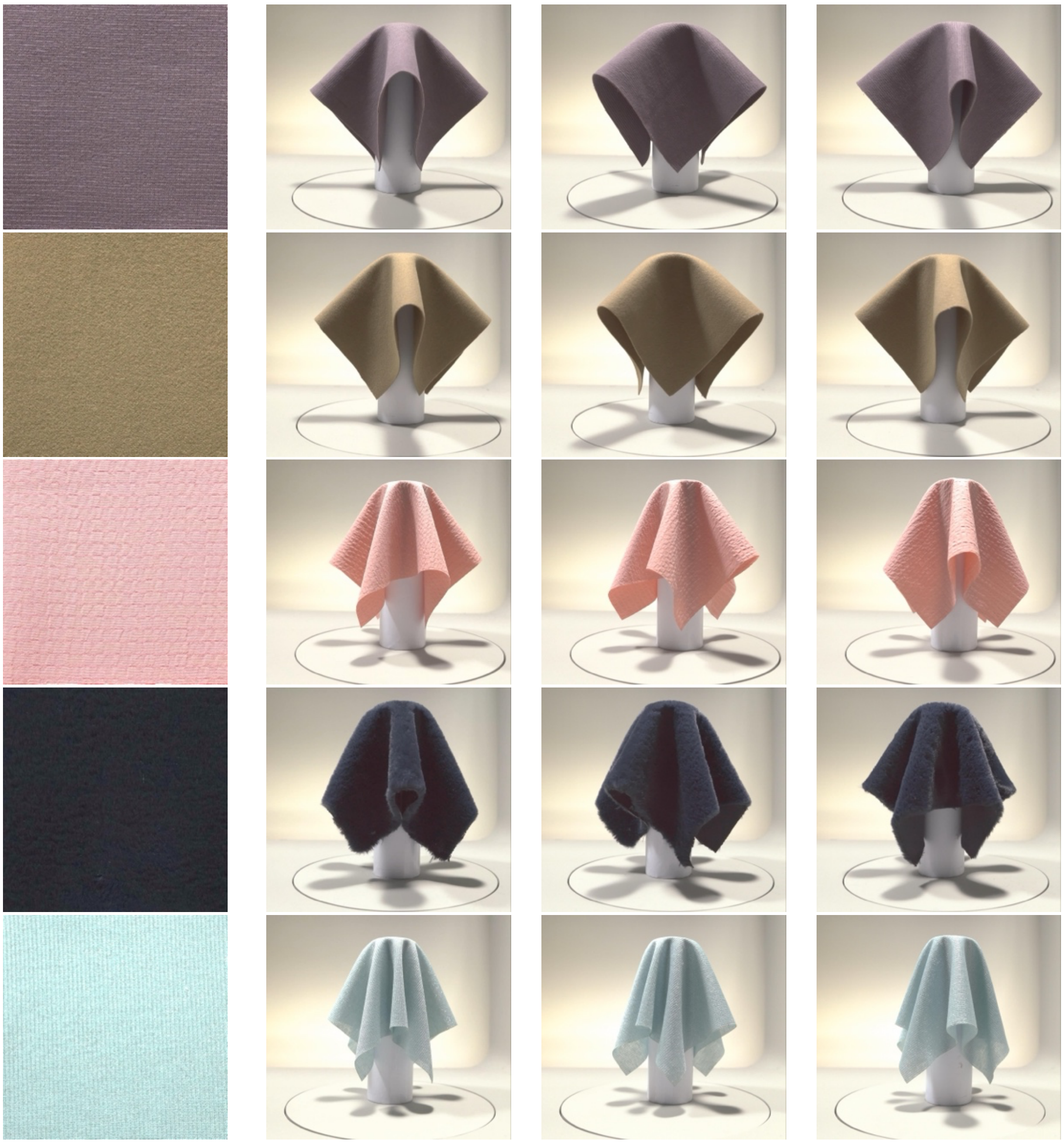

Figure 4: Example of the flat fabric images (the first column), and the draped fabric images when observing from different angles (the second column: drape_0, the third column: drape_45, the right column: drape_90). The first row: the perceived flexible-stiff showed the greatest difference between flat images (mean=3.10) and draped images (mean=6.52). Mean represents the average score given by subjects, as described in section 2.2.2. The second row: the perceived smooth-rough showed the greatest difference between flat images (mean=7.60) and draped images (mean=5.07). The third row: the perceived soft-firm showed no difference between flat images (mean=3.00) and draped images (mean=3.00). The fourth row: the perceived spongy-crisp showed no difference between flat images (mean=2.5) and draped images (mean=2.5). The fifth row: the perceived warm-cool showed the greatest difference between flat images (mean=4.10) and draped images (mean=6.57).

2.2.2. Psychophysical experiments

Six separate sets of perceived fabric tactile and visual-tactile properties evaluation data were collected through psychophysical experiments described as follows:

1. Flat: The flat fabric images calibrated through camera and display characterization models were presented on the calibrated BenQ display in random order.
2. Draped: The draped fabric images calibrated through camera and display characterization models were presented on the calibrated BenQ display in random order.
3. Video: The fabric rotating videos calibrated through camera and display characterization models were presented on the calibrated BenQ display in random order. The subjects were asked to watch the videos for at least 50 seconds before providing the tactile response.
4. Touch-only: Touch the fabric samples without observing them. The fabrics were passed to the subjects under the desk.
5. Vision-only: Observe the draped fabric samples rotating on the rotation stage in the VLB illuminated by the CIE D65 lighting, but not touch them.
6. Vision+touch: Observe and touch the fabric samples in the VLB illuminated by the CIE D65 lighting.

The experiments were conducted in a dark room. Eleven subjects (4 males; mean age ± SD=31.18 ± 4.98) participated in the six experiments. Nine of them completed all the experiments using 118 fabrics, and two of them completed all the experiments using 29 fabrics and 89 fabrics, respectively. The distance between the subject and the fabric sample is approximately 40 cm. In each experiment, subjects were required to make categorical judgements of flexible-stiff, smooth-rough, soft-firm, spongy-crisp, and warm-cool using a 9-point Likert-type scale, where 1 represented completely flexible / smooth / soft / spongy / warm and 9 represented completed stiff / rough / firm / crisp / cool. For the tactile descriptions, subjects were trained prior to the experiment to have a unified understanding:

- Flexible-crisp: (imagine) the fabric is draping over your hand. If you can clearly see the contour of your hand due to the draping fabrics rather than the translucency of the fabric, then the fabric is more flexible, otherwise is stiffer.
- Smooth-rough: (imagine) you are touching the surface of the fabric. If you feel no hairy and there is little force stopping your movement, then the fabric is smoother, otherwise is rougher.
- Soft-firm: (imagine) you are crushing the fabric into a ball in your hand. If you think it is very easy to crush it into a ball, then the fabric is softer, otherwise is firmer.
- Spongy-crisp: (imagine) you are crushing the fabric into a ball in your hand and then opening the palm and observing if the fabric bounces back. If it bounces back quickly, then the fabric is spongier; if not and creases are shown on the surface, then the fabric is crisper.
- Warm-cool: (imagine) you are putting the fabric over your hand. If you feel warmer, then the fabric is warmer; if you feel cooler, then the fabric is cooler.

To avoid the memory effect, observers were required to follow the experiment order designed above. To test the variability, two experiments, one from either experiment 1, 2, 3, one from either experiment 4, 5, 6, were repeated for all the observers.

2.3. Data analysis

The inter- and intra-observer variability was examined using the Root Mean Square (RMS), following studies that used the method of categorical judgement [20-22]. RMS indicates the difference between the two sets of responses from one observer, and how well individual agreed with the mean scale value, where 0 means perfectly agree. The RMS value is determined by the following:

$$\mathrm{RMS} = \sqrt{\frac{\sum_i (x_i - y_i)^2}{N}} \tag{1}$$

where N represents the number of observations; x_i represents an observer's tactile response in one set; y_i represents an observer's tactile response in the repeat set for assessing intra-observer variability, and the average response from all observers for assessing inter-observer variability; i represents the stimulus.

The experimental data were expressed as integer values that indicated the tactile responses evaluated under the corresponding conditions. The observed scores were averaged across all observers to create a score for each sample and each experiment. Given that in Experiment 2, three draped fabric images were extracted from the fabric rotating videos for each fabric, we first conducted a one-way ANOVA test to understand the effect of the observing angles. After that, the Pearson Correlation Coefficient (two-tailed) was used to assess the relationships of the tactile perception among different experiment conditions. The Pearson Correlation Coefficient value ranges from -1 to 1, where -1 means a perfect negative correlation, and 1 means a perfect positive correlation.

3. Results and discussions

3.1. Observer variability

The RMS values were calculated as a measure of both inter-observer variability and intra-observer variability for tactile responses across observers and the six experiments. As shown in Table 2, the RMS values range from 1.17 to 1.63 with a mean value of 1.38 for inter-observer variability, and from 0.94 to 1.34 with a mean value of 1.25 for intra-observer variability. The observer variability for warm-cool was found to be the lowest, with the RMS of 1.17 and 0.94, and the highest for spongy-crisp with the RMS of 1.63 and 1.34 for inter- and intra-observer variability, respectively. Compared to the studies using categorical judgement [20-22], the RMS values shown here are reasonable, indicating it can achieve observer variability within 1.38 points on a 9-point scale within the group, and 1.25 points on a 9-point scale within the observer.

Table 2
Observer variability for the 5 pairs of tactile descriptors

	Flexible-stiff	Smooth-rough	Soft-firm	Spongy-crisp	Warm-cool	Mean
Inter-observer variability	1.24	1.44	1.39	1.63	1.17	1.38
Intra-observer variability	1.26	1.34	1.34	1.34	0.94	1.25

3.2. The correlations of the tactile perception among the experiment conditions

The difference of the visual-tactile responses between the three observing angles (drape_0, drape_45, drape_90) from the draped fabric images was tested by the one-way ANOVA. Overall, there is no significant difference of the visual-tactile responses in each tactile property: F=0.025, p=0.976 for flexible-stiff; F=0.411, p=0.713 for smooth-rough; F=0.045, p=0.956 for soft-firm; F=0.586, p=0.559 for spongy-crisp; F=0.027, p=0.973 for warm-cool. The results indicated that the observing angles have no significant effects on the visual-tactile perception of draped fabric images. A possible reason is that, when subjects view one draped fabric image, it is likely they can imagine what the fabric would look like from different angles. To simplify, the visual-tactile responses averaged across the three observing angles are used in subsequent analysis to represent the visual-tactile responses obtained from the draped images.

Figure 5 shows the Pearson Correlation Coefficients of the tactile responses among the six experiment conditions, along with the corresponding significance levels.

When comparing the correlations of the tactile responses observed through displaying images and videos (black polygons in Figure 5), it is found that the correlations between the draped images and fabric rotation videos are always very high and significant for the five pairs of tactile properties($0.9<r<0.96$, $p<0.001^{***}$). It is reasonable because the draped fabric images in Experiment 2 were extracted from the videos used in Experiment 3. The observers, when observing the fabric rotation videos, certainly also observed the draped fabric images. On the other hand, the tactile properties of flexible-stiff, smooth-rough, soft-firm, and spongy-crisp observed from flat images were positively correlated with those observed from draped fabric images and videos ($0.67<r<0.81$, $p<0.001^{***}$). However, these correlations were not as high as the correlations between draped fabric images and fabric rotation videos as described above. It is noted that for warm-cool, the tactile responses obtained from flat fabric images, draped fabric images, and fabric rotation videos were highly consistent ($r>0.9$, $p<0.001^{***}$). What's more, the tactile properties perceived from flat fabric images showed a slightly stronger correlation with those perceived from draped fabric images than with those perceived from fabric rotation videos. A possible reason is that subjects observed the fabric rotation videos for at least 50 seconds before providing tactile responses, which is longer than the time spent on static fabric images.

The correlation coefficients shown in the blue rectangles in Figure 5 show how the different tactile properties perceived from fabric images and videos correlate with those from the actual touch and observation (touch-only, vision-only, vision+touch) of fabrics. Firstly, the tactile responses obtained from draped fabric images and rotating videos had similar correlations with the results obtained from actual touch and observation. Another study compared the tactile perception obtained from jean fabric images and videos [6]. Unlike our findings, they concluded that videos have a better identification performance over images in the match-to-sample task. It is noted that their videos included the process of manipulating the fabrics by human hand, whereas ours only featured the fabric itself. In the absence of the experience of hands touching the fabrics in the video, fabric images and videos played similar roles in conveying tactile properties. Secondly, the tactile perception obtained from flat fabric images had a lower correlation with the actual touch and observation compared to draped fabric images and videos, but for warm-cool, the correlations were very similar and highly positive. A previous study [10] found that draped fabric images had better matching accuracy than flat images in the match-to-sample task. A possible explanation of this discrepancy about warm-cool is that the perception of the tactile properties is a multiscale task [7,9,13-15]. Compared to draped fabric images and videos, flat fabric images lack information such as drape, shape, shade, and folds. The presence of such information enhanced the understanding of tactile properties in the absence of actual touch and observation, but they were less important for perceiving warm-cool

The orange polygons in Figure 5 show the correlations of the tactile responses obtained through the actual touch (touch-only), the observation (vision-only) and the combination of both (vision+touch). In this study, the vision+touch experiment provided subjects with the most comprehensive perception of the real fabrics. Among them, the correlations between the touch-only and vision+touch were the highest for flexible-stiff ($r=0.97$, $p<0.001^{***}$), smooth-rough ($r=0.95$, $p<0.001^{***}$), soft-firm ($r=0.97$, $p<0.001^{***}$), spongy-crisp ($r=0.86$, $p<0.001^{***}$). For the perception of warm-cool, the correlations were the same and the highest between touch-only and vision+touch ($r=0.94$, $p<0.001^{***}$) and between vision-only and vision+touch ($r=0.94$, $p<0.001^{***}$). Besides, we also found high and significant correlations of tactile perception between vision-only and vision+touch (minimum $r=0.78$, $p<0.001^{***}$ for spongy-crisp). In the absence of either vision or touch, consistent perception of tactile properties can be obtained using real fabrics.

When the fabric can be both observed and touched simultaneously (vision+touch), the visual traits (e.g., colour, texture, gloss) can be perceived by the observer. When perceiving the tactile properties in the absence of visual traits (the touch-only experiment), the tactile perception obtained was highly correlated with that of the vision+touch experiment. It appears that the absence of visual traits did not significantly influence the tactile perception. However, a significant role of colour has been found in a study comparing the tactile perception using draped fabric images in RGB condition and in greyscale condition by means of match-to-sample task [10]. Table 3 compares the experiment conditions with the study [10] and lists the visual traits which can be observed in both studies, including but not limited to colour, texture, and gloss. It is found that with the presence of visual traits except for colour, colour significantly affected. However, when all visual traits were not available, the impact of colour was no longer significant. We thus believe that the effect of colour only emerged in conjunction with other visual traits. It is important to clarify that the effect of colour here refers to the presence or absence of the colour, rather than the effects of difference colours.

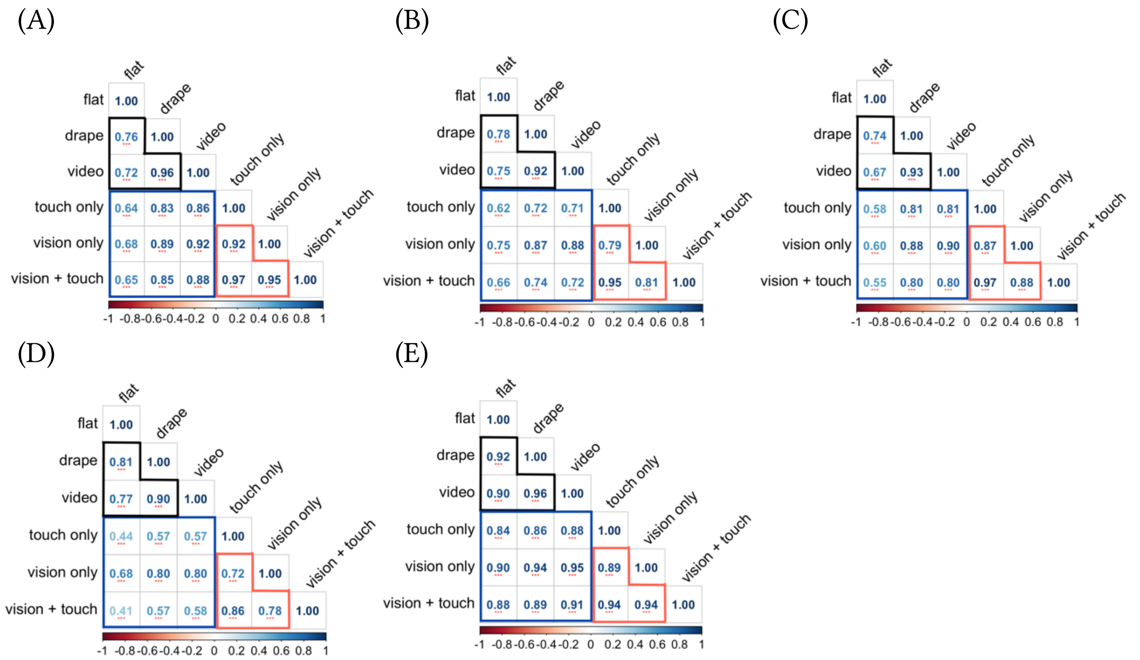

Figure 5: The Pearson Correlation Coefficient between each of the experiment conditions. (A): flexible-stiff; (B): smooth-rough; (C): soft-firm; (D): spongy-crisp; (E): warm-cool. Asterisks indicate the statistical significance: *p<0.05, **p<0.01, ***p<0.001.

Table 3
A comparison of the experiment conditions between [10] and our study

Visual traits that can be seen (✓) or not (X)	RGB image [10]	Greyscale image [10]	Vision+touch	Touch-only
Colour	✓	X	✓	X
Texture	✓	✓	✓	X
Gloss	✓	✓	✓	X
Others	✓	✓	✓	X
	Significant RGB effects		Highly correlated results	

4. Conclusion

This study demonstrated a comprehensive understanding of the tactile properties, including flexible-stiff, smooth-rough, soft-firm, spongy-crisp, and warm-cool of the fabrics. Fabrics were presented and evaluated in the form of images (flat and draped) and videos (rotating), and real fabrics under the conditions of touch-only, vision-only, and the combination of both. Firstly, we found no significant difference of the tactile perception between viewing angles. Secondly, we demonstrated the importance of evaluating different tactile properties. It is necessary to use different descriptors to describe the tactile properties rather than treat them as a whole. The perception of flexible-stiff, smooth-rough, soft-firm, and spongy-crisp exhibited similar trends:

the tactile properties perceived from draped images and videos showed no significant difference, and more closely correlated with the actual touch and observation than the perception from flat images. However, the perception of warm-cool was different: the tactile responses were highly correlated under the six conditions in this study, regardless of whether images or real fabrics were used. Consistent perception of the tactile properties in this study can be obtained from real fabrics, either in the absence of vision or touch. Next, by comparing the experiment conditions with the other study, we also found that colour only had a significant effect in conjunction with other visual traits, where 'colour' referred to its presence or absence.

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