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SUBJECTIVE EVALUATION OF DIGITAL PROTECTIVE MATERIALS

The research aims to evaluate the level of perception of tactile and visual characteristics of digital protective textiles materials compared with the same materials in physical format. First, the materials were scanned using the TAC7 system and their appearance was captured in a unique digital format. Next, the digital materials were processed using Keyshot rendering software and a number of three different digital evaluation scenarios were defined: S1-image, S2-video animation and S3-3D object, where it is possible to rotate and enlarge/shrink the material, the fourth evaluation scenario is represented by the physical materials. In the last stage, by applying a questionnaire based on a Likert rating scale from 1 to 7, data were collected from 24 subjects regarding the levels of perception of tactile and visual characteristics (subjective perception) of digital and physical materials, in each of the four mentioned scenarios. Boxplot diagrams were used to evaluate the subjects' level of agreement on the perception of materials characteristics and the Friedman test was applied to evaluate and compare the perception from the three digital scenarios with the perception of physical materials from the fourth scenario. The results show a lower degree of agreement for digital materials compared to the physical ones and highlighted glossiness, colour and transparency having the highest level of agreement in all scenarios. Correlations between the materials' attributes were high between softness, draping, elasticity and thermal sensation. Comparative analysis between scenarios highlights the difficulty of transposing tactile attributes into digital format compared with the visual attributes.

Keywords: Scanning; Digitalization; Protective Materials; Rendering; Subjective Evaluation

1. Introduction

The recognition of material properties from digital formats is capitalized on by several research papers that aimed to obtain learning techniques and recognition tasks [1,2], which demonstrate that images of physical materials in digital format have enough details that can be recognized. At the same time, various applications for materials recognition are researched and developed globally [3,4].

According to research conducted by K. Schröder et al., translating a textile material into a virtual gallery for physical reasons at the wire level is a complex process due to the underlying geometrical and optical complexity. Their study aimed to represent large-size textiles in a digital format with accurate physical rendering. The materials chosen for the study are a rough-looking carpet, a soft-looking blanket, and a translucent curtain. The conclusion is that rendering the structure of the materials in the image is very complicated due to the limited storage of absorbed and reflected light. Where the density of the material structure is higher, the structure and colours can be visually reproduced much more easily in digital format [5].

Viewing an object or material in a digital format depends on a multitude of factors that influence our perception. A key factor is represented by how light is reflected, scattered, and absorbed by the object's texture. From the beginning, computer graphics software challenged the light factor to make it possible to translate and render the most realistic visualization of materials in digital format. To achieve this, it is necessary to understand how objects interact with light so that the physical characteristics of the material can be fully represented: structure, colour, gloss, additional information, and rigid/smooth/rough/velvety textures [6-9].

2. Methodology

This paper assesses the level of perception of digital protective materials in comparison with the tactile and visual characteristics of physical materials. The perception of digital textile protective materials is evaluated relating to tactile and visual stimuli transposed as an image (Scenario S1), a video animation in which the material is in motion (Scenario S2), a 3D interactive object (Scenario S3) in which the subject can rotate

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and increase the size of the object and the actual physical materials (Scenario S4). To evaluate the protective materials in digital format, several steps have been completed, as presented in Fig. 1.

Digitising physical materials in a virtual format

Six waterproof textile materials used for manufacturing protective clothing were selected for scanning with the TAC7 ecosystem, having a sample size of 29,7×21 cm (A4). After scanning, materials digital data are obtained in *.axf format, which are digital files containing all the characteristics of the scanned materials including metadata information (database schema) [10,11]. Fig. 2 presents the six scanned waterproof materials.

Rendering scanned materials and defining the evaluation scenarios in digital format

The first step to render the materials in the Keyshot [12] software is to import the 3D object on which the digital material will be shaped (Fig. 3). In the second step, import the scanned material containing its texture maps and assign it to the 3D object (Fig. 4). In the third step, before rendering, to get a realistic

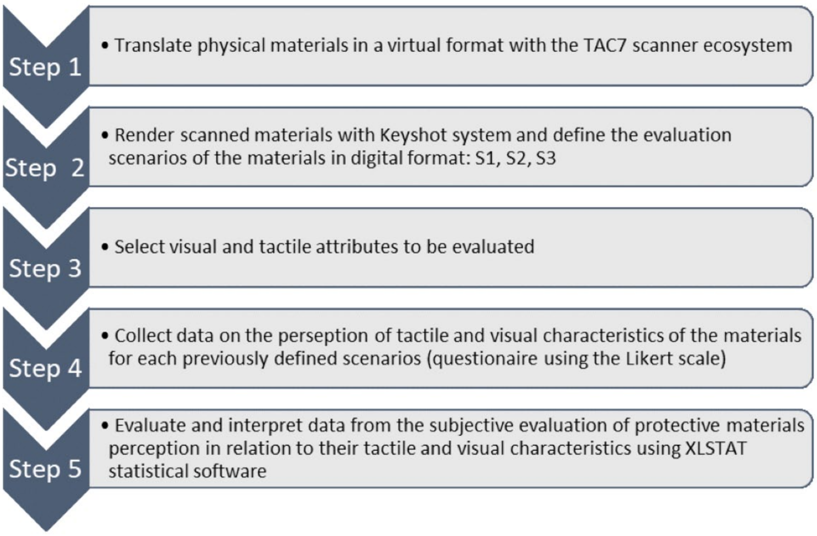

Fig. 1. The stages of obtaining and evaluating textile digital materials

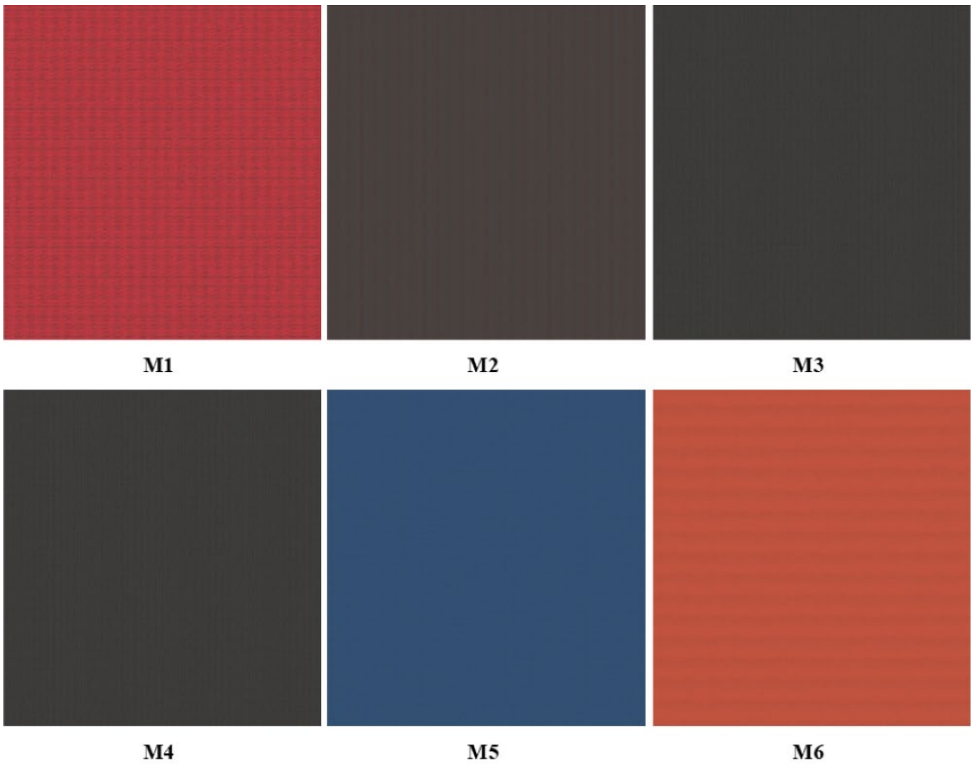

Fig. 2. Scanned waterproof textile materials

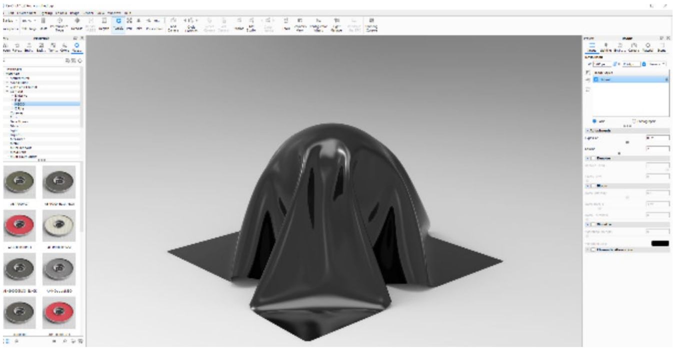

Fig. 3. Import the 3D shape into the Keyshot program

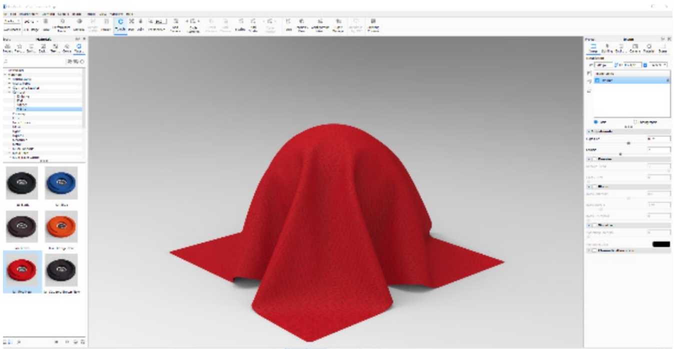

Fig. 4. Assign scanned material to the 3D shape

representation of the scanned material, define the UV parameters mapping (Fig. 5). To have the same representation of the scanned and rendered materials, the first three steps are the same and done only once for all three digital scenarios, using the same 3D object and same rendering parameters. The last step is to define the rendering settings for each scenario individually, depending on the output, picture, video and 3D interactive object (Fig. 6).

For scenario S1, the settings for rendering the materials as a picture are the following: output format JPEG, image size 2560 pixels width by 1440 pixels height and 300 dpi resolution. Final rendered materials for scenario S1 are presented in Fig. 7.

For scenario S2, the settings for rendering the materials as a video are the following: camera position and orientation

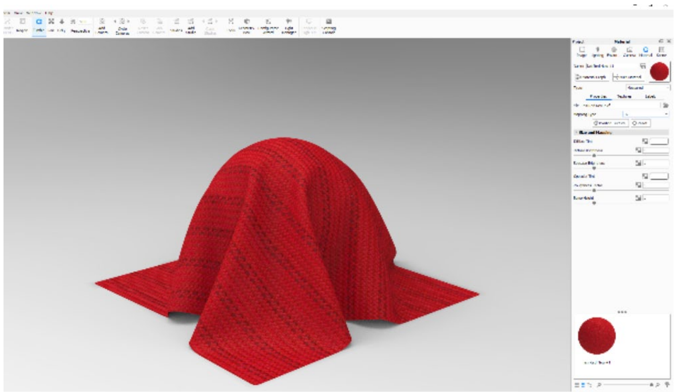

Fig. 5. Define UV reference parameters

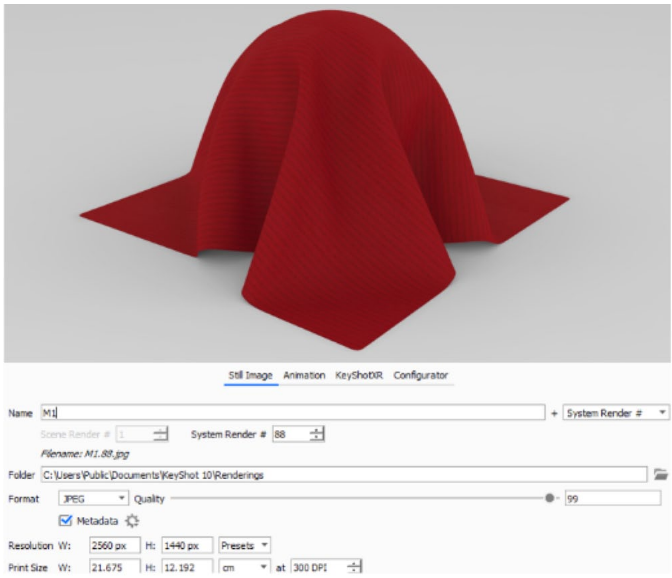

Fig. 6. Set image rendering parameters

(angle '–45 degrees', tilt '20 degrees', focus' –15.59, 36.24, 19.92' and camera focus distance set to 800 mm), 'Turntable' animation type (camera rotation set to 360 degrees in a clockwise direction, with a duration of 15 seconds at 60 FPS (frames per second) and a resolution of 2560 pixels by 1440 pixels. As an

Fig. 7. Final rendered materials for scenario S1 – image

example, Fig. 8 presents a capture of the final representation of M5 material in as video.

For scenario S3, the materials were rendered as interactive 3D objects using the KeyshotXR [12] module and with the following settings: camera (target at the centre of rotation, focus distance set to 900 mm, object angle –45 degrees and camera tilt 30 degrees), number of frames (26 horizontally and 16 vertically resulting a total of 416 frames for each object), object level of interaction (start horizontal angle –50 degrees, end horizontal angle 50 degrees, start vertical angle 10 degrees and end vertical angle 70 degrees), image resolution 1920×1080 pixels and maximum zoom at 200%. Processing time was on average 28 hours for each material, being higher for materials that had a higher degree of transparency. As an example, Fig. 9 presents a capture of the final representation of M5 material as a 3D interactive object.

To mitigate potential misinterpretation among participants, the initial phase of the study facilitated exclusive visual engagement with materials available solely in digital format, encompassing the perspectives outlined in the first three scenarios. Subsequently, during the experiment‘s conclusive phase, partici-

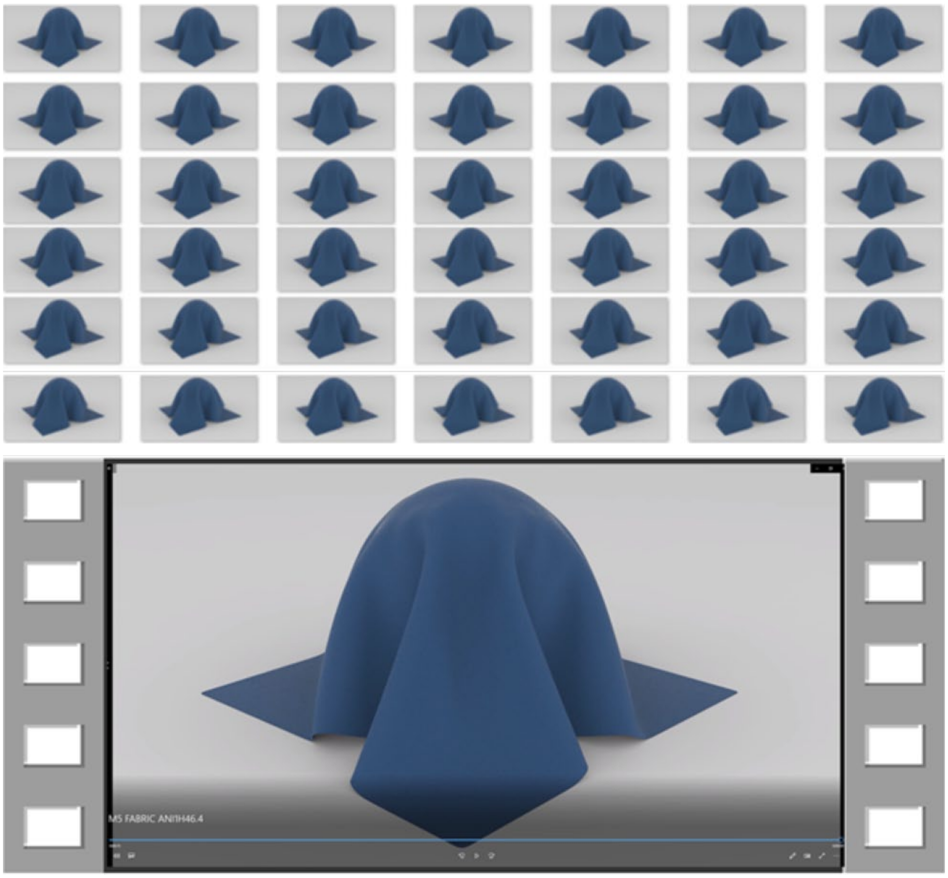

Fig. 8. The final representation of the M5 material as a video

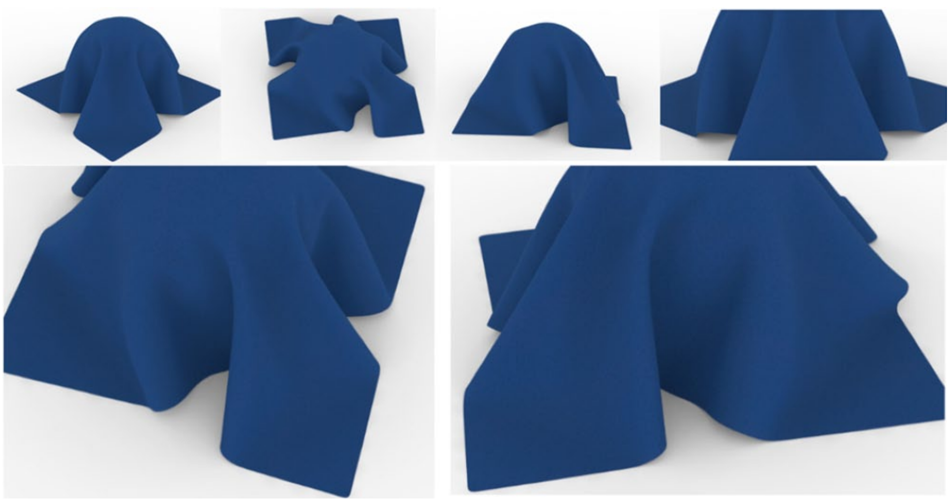

Fig. 9. The final representation of the M5 material as a 3D interactive object

pants were afforded direct interaction with physical materials. This phase notably involved the presentation of samples sized approximately at 20×30 cm. A visual representation of the four evaluation scenarios is depicted in Fig. 10.

Selecting visual and tactile attributes of materials for evaluation

There is a wide range of parameters that influence human perception of textile properties, which are classified into two main categories, namely visual parameters and tactile parameters. Textile protective materials' descriptive visual and tactile attributes are to be evaluated were resected considering the level of difficulty related to recognizing and perceiving digital materials. Evaluating these attributes will have a constructive contribution to the development and improvement of digital databases of protective textile materials. The descriptive attributes were selected by reviewing existing research.

Visual characteristics were selected according to the previous research, by summarizing the main visual properties of textile materials as follows: gloss, colour, roughness and transparency/opacity [13-19]. Respectively, the tactile attributes were selected according to the same principle as the visual attributes, as follows: softness drape, elasticity/stretch properties, degree of friction, thermal sensation, the sensation of humidity/hygroscopicity [20-25]. It is considered that the set of selected attributes will cover the degree of recognition and perception of visual qualities based on previous experiences of subjects. Since protective materials represent different characteristics and properties, visual and tactile attributes with opposite sets of characteristics (bipolar) have been selected using the method proposed in the reference work [26]. The selected attributes are resented below in TABLE 1.

Fig. 10. Diagram of material perception in scenario S1, S2, S3, S4

TABLE 1

Visual and tactile attributes

Abr.	Evaluated attributes	1	2	3	4	5	6	7
ML	Gloss	Mat						Glossy
UM	Colour	Uncoloured						Multi-coloured
RM	Roughness	Rough						Silky
TO	Transparency	Transparent						Opaque
FR	Softness	Flexible						Rigid
GU	Drape	Heavy						Easy
ER	Elasticity	Elastic						Rigid
SG	Thickness	Thin						Thick
AA	Friction	Slippery						Adherent
CR	Thermal sensation	Warm						Cold
NA	Hygroscopicity	Non-absorbent						Absorbent

Collecting data on the perception of tactile and visual characteristics of textile protective materials

To collect data on the perception of tactile and visual characteristics of textile protective materials, a set of questionnaires based on the Likert scale were used [27]. This method was selected because it is considered the most effective method when evaluating and obtaining plausible data in evaluating a product [18]. Observers were asked to rate 4 visual attributes, and 7 tactile attributes, using a 7-point numerical Likert scale. For example, if the subject considers the viewed material to be perceived as 'soft', he must tick the number 7, if he considers the material to be of average softness, he must tick the number 4, and if the material is considered rigid, the subject must tick 1

The assessment involved 24 subjects aged between 22 and 59 years old. All subjects participated voluntarily in this experiment. Subjects are professionals from the textile industry, being more critical and objective in assessing the materials. Previously to the evaluation, the subjects were trained on the evaluation procedures and process.

3. Results and Discussion

Subjective evaluation of the perception of bipolar attributes concerning experts' degree of agreement

For each of the four scenarios, a box plot diagram was used for the analysis and interpretation of the distribution of the variables that were selected from the subjects' subjective assessments of how they perceived the protective materials. The main aim of this evaluation is to assess the degree of subject agreement regarding how the examined materials are perceived by the participants and the relationships between how the materials are perceived from the perspective of the analyzed bipolar attributes. Fig. 11 shows the box plot diagram of the subjects' level of agreement on the perception of the materials analysed in scenario S1.

The minimum and maximum values are distributed as follows:

- Minimum and/or maximum values are outside the whiskers in the case of bipolar attributes ML, UM, TO, FR, and NA;
- Minimum and maximum values are inside whiskers for bipolar attributes RM, GU, ER, SG, AA, and CR.

Distribution of the minimum and maximum values inside the whiskers is observed for the majority of the analysed bipolar attributes (6 out of 11). They represent extremes outside the normal distribution indicating a low degree of agreement among the subjects. For S1, a high degree of agreement among subjects is observed for most attributes.

The distribution degree of symmetry is as follows:

- The distribution of perception is approximately centred in the case of bipolar attributes RM, FR, GU, ER, SG, AA, CR, and NA;
- The distribution is asymmetric to the right (low scores prevail) in the case of bipolar attributes ML, UM;
- The distribution is the perception is asymmetric to the left, the high scores prevail in the case of the bipolar TO attribute.

The degree of symmetry indicates the level of agreement of the subjects on the degree of polarity of the analysed attributes. There is polarization in the case of 3 attributes out of 11.

As for the height of the box, the results are as follows:

- The height of the box is high, which indicates a flat distribution, in the case of bipolar attributes SG and CR;
- The height of the box is reduced, which indicates a sharp distribution, namely that the majority groups around the median, in the case of bipolar attributes ML, UM, RM, TO, FR, GU, ER, AA, and NA.

A low box height indicates a high degree of agreement among the subjects in the case of 9 attributes.

Fig. 12 shows the box plot diagram of the subjects' level of agreement on the perception of the materials analysed in scenario S2.

The minimum and maximum values are distributed as follows:

- Minimum and/or maximum values are outside the whiskers in the case of bipolar attributes ML, UM, TO, FR, ER, and SG;

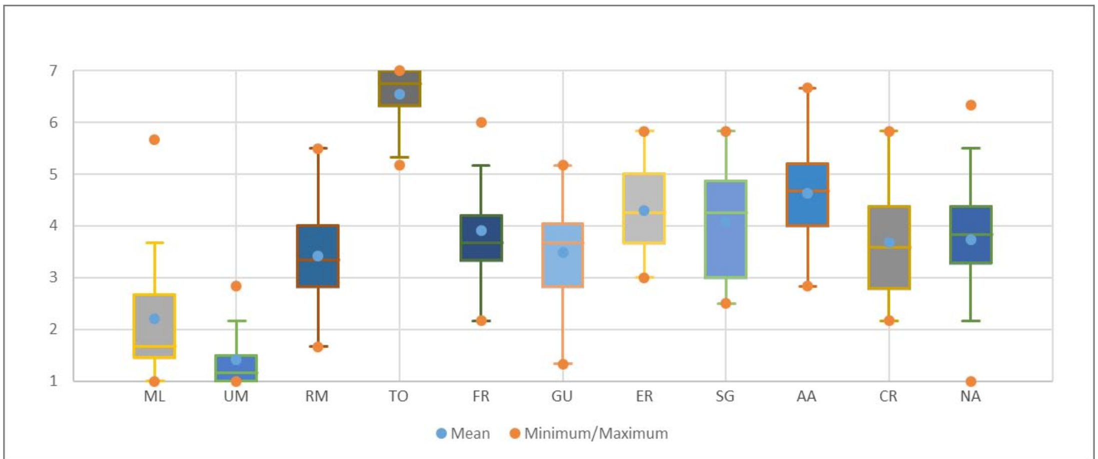

Fig. 11. Diagram of material perception in scenario S1

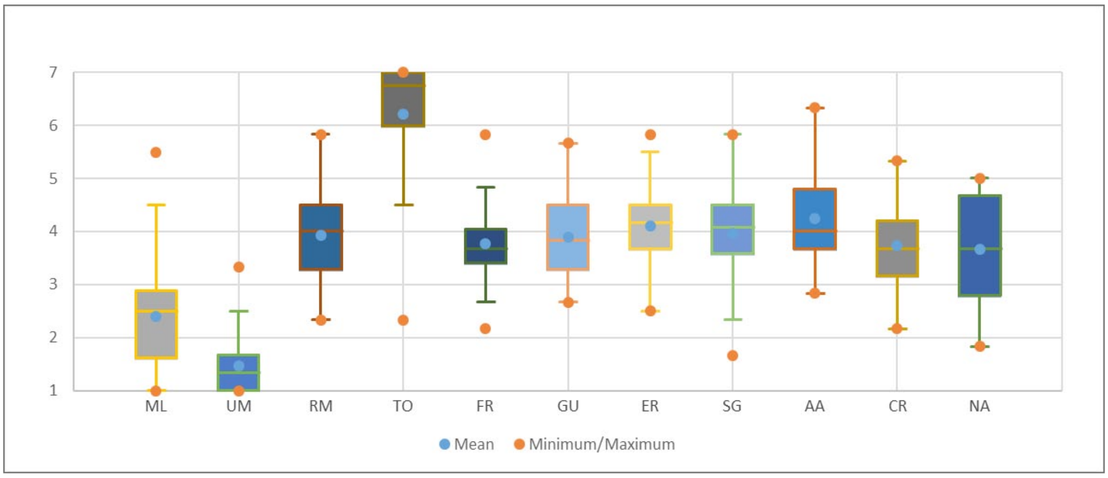

Fig. 12. Diagram of material perception in scenario S2

- Minimum and maximum values are inside whiskers for bipolar attributes RM, GU, AA, RC, and NA.

Distribution of the minimum and maximum values outside the whiskers is observed for the majority of the analysed bipolar attributes (6 out of 11), indicating a low degree of agreement among the subjects for most of the analysed attributes.

The distribution degree of symmetry is as follows:

- The distribution of perception is approximately centred in the case of bipolar attributes RM, FR, GU, ER, SG, AA, CR, and NA;
- The distribution is asymmetric to the right (low scores prevail) in the case of BIPOLAR ATTRIBUTES ML and UM;
- The distribution is the perception is asymmetric to the left, the high scores prevail) in the case of the bipolar TO attribute.

The degree of symmetry indicates the level of agreement of the subjects on the degree of polarity of the analysed attributes. There is polarization in the case of 5 attributes out of 11.

As for the height of the box, the results are as follows:

- The height of the box is high, which indicates a flat distribution, in the case of bipolar attribute NA;
- The height of the box is reduced, which indicates a sharp distribution, namely that the majority groups around the median, in the case of bipolar attributes ML, UM, RM, TO, FR, GU, SG, AA, and CR.

A low box height indicates a high degree of agreement among the subjects in the case of 10 attributes.

Fig. 13 shows the box plot diagram of the subjects‘ level of agreement on the perception of the materials analysed in scenario S3.

The minimum and maximum values are distributed as follows:

- Minimum and/or maximum values are outside the whiskers for bipolar attributes ML, RM, TO, FR, and CR;
- Minimum and maximum values are inside the whiskers for the bipolar attributes UM, GU, ER, SG, AA, and NA.

Distribution of the minimum and maximum values within the whiskers is observed for most of the analysed bipolar attributes (6 out of 11), indicating a high degree of agreement among the subjects for most of the analysed attributes.

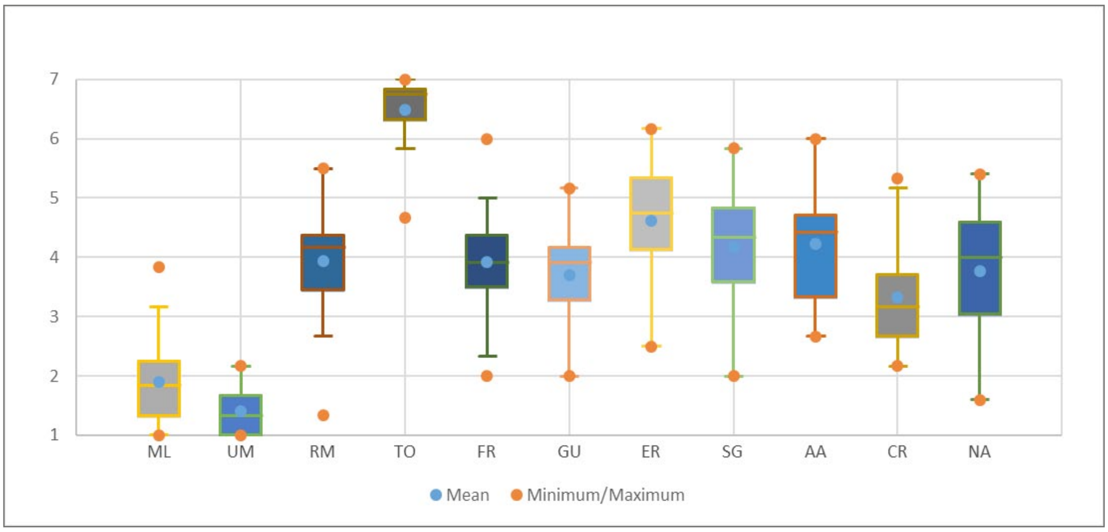

Fig. 13. Diagram of material perception in scenario S3

The distribution degree of symmetry is as follows:

- The distribution of perception is approximately centred in the case of bipolar attributes RM, FR, GU, ER, SG, AA, CR, and NA;
- The distribution is asymmetric to the right (low scores prevail) in the case of bipolar attributes ML and UM;
- The distribution is the perception is asymmetric to the left, the high scores prevail) in the case of the bipolar TO attribute.

The degree of symmetry indicates the level of agreement of the subjects on the degree of polarity of the analysed attributes. There is polarization in the case of 3 attributes out of 11.

As for the height of the box, the results are as follows:

- The height of the box is high, which indicates a flat distribution, in the case of bipolar attributes AA and NA;
- The height of the box is reduced, which indicates a sharp distribution, namely that the majority groups around the median, in the case of bipolar attributes ML, UM, RM, TO, FR, GU, ER, SG, and CR.

A low box height indicates a high degree of agreement among the subjects in the case of 9 attributes.

Fig. 14 shows the box plot diagram of the subjects' level of agreement on the perception of the materials analysed in scenario S4.

The minimum and maximum values are distributed as follows:

- Minimum and/or maximum values are outside the whiskers in the case of bipolar TO, AA, and NA attributes;
- Minimum and maximum values are inside whiskers for bipolar attributes ML, UM, RM, FR, GU, ER, SG, and CR.

Distribution of the minimum and maximum values within the whiskers is observed for most of the analysed bipolar attributes (8 out of 11), indicating a high degree of agreement among the subjects for most of the analysed attributes.

The distribution degree of symmetry is as follows:

- The distribution of perception is approximately centred in the case of bipolar attributes ML, RM, FR, GU, and CR;
- The distribution is asymmetric to the right (low scores prevail) in the case of bipolar attributes UM, SG, and NA;
- The distribution is the perception is asymmetric to the left (the high scores prevail), in the case of the bipolar TO and ER attribute.

The degree of symmetry indicates the level of agreement of the subjects on the degree of polarity of the analysed attributes. There is polarization in the case of 5 attributes out of 11.

As for the height of the box, the results are as follows:

- The height of the box is high, which indicates a flat distribution, in the case of bipolar attributes ML, FR, GU, and CR;
- The height of the box is reduced, which indicates a sharp distribution, namely that the majority groups around the median, in the case of bipolar attributes UM, RM, TO, ER, SG, AA, and NA.

Comparative analysis of the analysed bipolar attributes between scenarios

The inter-scenario analysis considered the comparison of scenarios S1, S2 and S3 represented by the digital materials with scenario S4 represented by the physical materials. This analysis aimed to understand how the perception of digital materials differs compared to physical materials. For the evaluation and comparison of the four scenarios the Friedman test was applied, the analysis taking into account that the data are dependent, the same subjects were interviewed and the scenarios were compared in pairs, S4 being the reference scenario.

TABLE 2 shows the comparison between the pairs of scenarios S4-S1, S4-S2 and S4-S3 by reference to the difference in means. The closer the difference between the means is to 0, the closer the S1-S3 scans are to the S4 scenario. Results marked in bold highlight representative differences from the S4 scenario.

TABLE 3 shows the comparison of the pairs of scenarios S4-S1, S4-S2 and S4-S3 by reference to the *p*-values. The closer the *p*-values are to 1, the closer the S1-S3 scenarios are to the S4 scenario. Results marked in bold highlight representative differences from the S4 scenario.

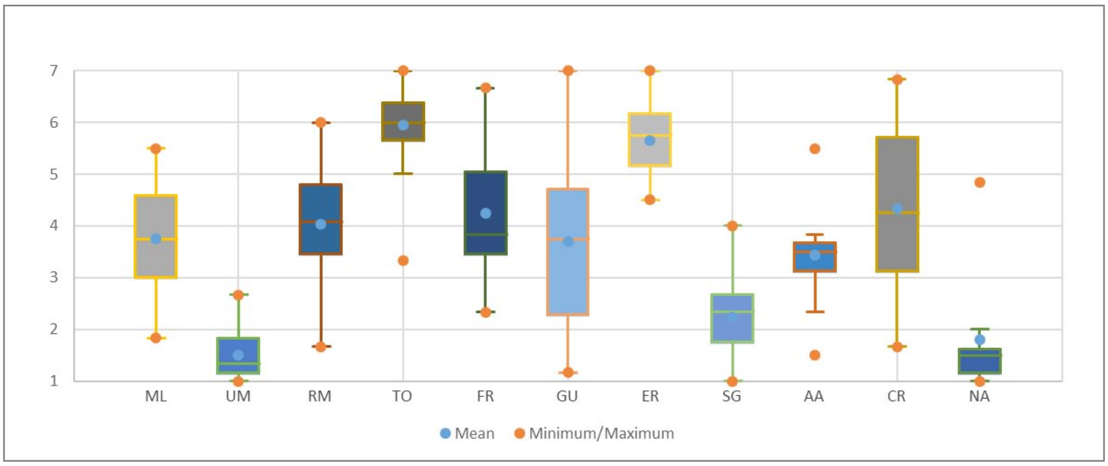

Fig. 14. Diagram of material perception in scenario S4

TABLE 2

Comparison between scenarios by reference to the difference in means

Attribute		Difference of means		
	Scenario	S1	S2	S3
ML	S4	1.438	1.146	1.750
UM	S4	0.333	0.313	0.354
RM	S4	0.833	0.354	0.313
TO	S4	**–0.979**	–0.646	–0.875
FR	S4	0.167	0.500	0.083
GU	S4	0.188	–0.375	–0.146
ER	S4	1.438	1.833	1.063
SG	S4	–2.000	–1.729	–1.938
AA	S4	–1.667	–1.167	–1.083
CR	S4	0.438	0.333	**1.063**
NA	S4	–1.583	–1.438	–1.563

TABLE 3

Comparison between scenarios by reference to *p*-values

Attribute		*p*-value		
	Scenario	S1	S2	S3
ML	S4	**0.001**	**0.012**	**<0.0001**
UM	S4	0.808	0.836	0.778
RM	S4	0.117	0.778	0.836
TO	S4	**0.045**	0.309	0.090
FR	S4	0.970	0.537	0.996
GU	S4	0.958	0.746	0.980
ER	S4	**0.001**	**<0.0001**	**0.024**
SG	S4	**<0.0001**	**<0.0001**	**<0.0001**
AA	S4	**<0.0001**	**0.011**	**0.021**
CR	S4	0.644	0.808	**0.024**
NA	S4	**0.000**	**0.001**	0.000

Significant differences are observed in the case of attributes ML, ER, SG, AA and NA for all three scenarios S1-S3 compared to scenario S4, which highlights the difficulty of transposing these attributes in digital format. The difficulty of transposing the ML attribute, which is a visual attribute, may be due to the technical conditions of scanning and rendering. The differences in the ER, SG, AA and NA attributes highlight the difficulty of translating tactile attributes into digital format. In the case of the TO and CR attributes, significant differences are highlighted in the case of scenarios S1 and S3, respectively. The differences in the case of the TO attribute, scenario S1, highlight that the representation of static three-dimensional materials in scenario S1, by comparison with scenarios S2 and S3 in which the materials are represented three-dimensionally but in motion, did not allow identification of the degree of transparency of the materials. The differences in the case of the CR attribute, scenario S1, may be motivated by the ability of the subjects to interact with the digital material (rotate and zoom in/out), although they could view the materials in more detail, the subjects were misled or made different decisions. In the case of the UM, RM, FR and GU attributes, no significant differences are highlighted in scenarios S1-S3 compared to scenario S4. In the case of the UM attribute, the results are similar in all three scenarios and close to 1, which highlights the similar perception of material color in all three digital representation scenarios. In the case of the RM attribute, the values are similar and close to 1 in the case of scenarios S2 and S3, the lowest value being in the case of S1, a fact that highlights the difficulty of transposing the roughness of materials through a static image. In the case of the FR and GU attributes, the values are similar and close to 1 for the S1 and S3 scenarios, but without significant differences in the S2 scenario, a fact that highlights the connection between the FR and GU attributes.

Establishing correlation coefficients to observe association between scenarios

Correlation coefficients were established to observe the association of scans S1, S2 and S3 relative to scenario S4. The data obtained are presented in TABLE 4.

TABLE 4

Values of correlation coefficients for scenarios S1-S3 compared to S4

Attribute	Correlation coefficients		
	S1-S4	S2-S4	S3-S4
ML	–0.258	0.280	0.111
UM	0.205	–0.017	0.080
RM	–0.050	**0.370**	–0.255
TO	**0.328**	**0.433**	–0.007
FR	**–0.310**	0.154	0.154
GU	–0.123	–0.018	0.256
ER	0.080	**0.438**	0.037
SG	0.207	**0.315**	0.099
AA	–0.010	**0.548**	0.109
CR	**–0.362**	**0.458**	–0.102
NA	–0.094	–0.134	–0.133

According to the data in the TABLE 4, for scenario S1 medium correlations are found in the case of the attributes TO, FR and CR, for scenario S2 high correlations are found in the case of the attribute AA and medium correlations in the case of the attributes RM, TO, ER, SG and CR and for scenario S3 only low and very low correlations are encountered. Most bipolar attributes statistically dependent on S4 are found in S2.

4. Conclusions

The subjective evaluation of the perception of bipolar attributes in relation to the degree of agreement of the experts involved the calculation of the statistical indicators of characterization and variation of the characterization attributes of textile materials and the highlighting of the indicators using boxplot diagrams. Due to the absence of standardized deviation criteria for assessing textiles through digital imagery, the precise interpretation and anticipation of regular deviations have proven challenging.

Regarding the range of minimum and maximum values, noteworthy findings emerged from the comparison of scenarios. The S4 scenario exhibited a notably higher consensus, as expected, encompassing agreement across 8 out of 11 attributes. Notably, within this scenario involving physical interaction with material alongside its digital counterpart, the attribute 'GU' (heavy–easy) exhibited maximum values, indicative of the substantial challenges inherent in discerning this attribute within a digital framework. Conversely, the S2 scenario yielded the lowest level of consensus across attributes, displaying concordance in only 5 out of 11 attributes. Particularly notable were the maximal values associated with attributes 'TO', 'FR', 'ER', and 'SG', signaling discernible discrepancies in perceiving these attributes within differing subjective contexts of physical and digital realms.

The degree of symmetry of the distribution revealed a high level of agreement of the subjects in the case of attributes ML, UM (asymmetry to the right) TO (asymmetry to the left, in the case of the other attributes the distribution being approximately central. Related to the height of the box, it was reduced for most bipolar attributes for all four scenarios, indicating a clustering around the median of most responses.

Regarding the comparative analysis between the scenarios of the analysed bipolar attributes, the Friedman test was applied and the scenarios were compared on a pairwise basis, S4 being the reference scenario. Substantial variations were discerned across multiple attributes when comparing scenarios S1, S2, and S3 against scenario S4. Notably, attribute ML demonstrated values of 1.438, 1.146, and 1.750 for scenarios S1, S2, and S3, respectively. Similarly, attribute ER exhibited values of 1.438, 1.883, and 1.938 in corresponding scenarios. Additionally, attribute SG displayed values of –2, –1.729, and –1.938, while attributes AA and NA portrayed values of –1.667, –1.167, –1.083, and –1.583, –1.438, –1.563 for scenarios S1, S2, and S3, respectively. These significant variations emphasize the complexity involved in effectively translating such attributes into a digital framework. The difficulty of transposing the ML attribute, which is a visual attribute, may be due to technical scanning and rendering conditions. The differences in the ER, SG, AA and NA attributes highlight the difficulty of translating tactile attributes into digital format. In the case of the UM, RM, FR and GU attributes, no significant differences are highlighted in scenarios S1-S3 compared to scenario S4. In the case of the UM attribute, the results are similar for all three scenarios and close to 1, which highlights the similar perception of material colour in all three digital representation scenarios. In the case of the RM attribute, the values are similar and close to 1 in the case of scenarios S2 and S3, the lowest value being in the case of S1, a fact that highlights the difficulty of transposing the roughness of materials through a flat image. In the case of the FR and GU attributes, the values are similar and close to 1 for the S1 and S3 scenarios, but without significant differences in the S2 scenario, a fact that highlights the connection between the Softness and Drape attributes.

To foster advancements, it's recommended to invest in research and development endeavors facilitating the evaluation and quantification of parametric characteristics within digitized materials. This entails enhancing current digitization systems to encompass attributes such as brightness, transparency, roughness, color, among others, broadening the scope of analysis. Integrating these developments into virtual product design processes would further amplify their impact.

Considering a broader research focus on subjective evaluations of digital images by engaging diverse participant categories beyond textile experts could yield valuable insights. Leveraging these findings might lead to the creation of beneficial tools for digital commerce purposes.

Exploring the impact of digitized textiles on the sustainability of the textile industry is crucial. Evaluating how the utilization of digitized textile materials affects various industry activities – including product development, design, prototyping, logistics, and sales – would provide invaluable insights. Employing tools to measure and quantify the effects of using digitized textile materials, encompassing aspects like costs, time, and carbon footprint, could significantly contribute to implementing sustainable practices within the industry.

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