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Interaction of Material Design Elements for Improved Human Tactile Comfort

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ABSTRACT

When it comes to textiles and clothing, human comfort is usually seen as a fundamental need for clothing wearers. This study focuses on the segment of the tactile comfort of textiles. The aim of this study is to determine the effects of material engineering (in terms of different compositional and structural designs of materials used in the manufacture of sportswear) on human perception of the tactile properties of materials. In this study, the focus was placed on the bipolar attributes roughness-smoothness (S-R), which were evaluated by a group of volunteers. For the purpose of evaluation, a set of adequate sportswear materials were selected. The selection of materials was based on the criteria of representativeness (the materials must be representative of the sportswear manufacture), and diversity of yarns (use of different yarns such as standard and recycled polyester, addition of elastane component into the structure to improve the comfort and garment fit). In order to be able to compare the outcomes of the material evaluation conducted by recruited evaluators, additional instrumental measurements were carried out and placed in the context of the subjective results. A roughness tester was used for this part of the measurement. According to the results, the difference between the designed materials in terms of the observed attributes is significant. This leads to the conclusion that the selection of an unsuitable material from the group of investigated materials should lead to an unsatisfactory comfort level and possibly to a less successful performance of an athlete.

Keywords: Material, Design, Yarn, Tactile, Comfort, Roughness

INTRODUCTION

When it comes to textiles and clothing, human comfort is usually seen as a basic need for clothing wearers. It is defined as a pleasant state resulting from the harmony between a human being and his environment involving textile material. In general, human comfort when wearing clothing can be divided into three different categories, among which each one gives its contribution towards the described harmony, as well as towards the optimal human performance. Among different types of comfort classifications, the most used is the one that focuses at the tactile comfort (also known as the fabric hand), thermophysiological comfort, and aesthetic/physiological comfort. Among each of these groups, there is a number of different material properties that should be considered. The first two categories are strongly influenced by material and garment properties. For example, the investigation of thermophysiological comfort is dominantly focused at the investigation of the transfer of heat and water vapour (i.e. sweat) trough textile material. The investigation of touch comfort (i.e. fabric hand) excludes those two parameters and focus at the investigaton of properties like softness, roughness, elasticity, etc. The last category (i.e. aesthetic/physiological comfort) depends on subjective perceptions and trends.

Tactile comfort is primarily associated with material properties and is briefly described as the feel of the material on the human body. As such, it is an intrinsic and essential performance requirement for functional and innovative clothing. Due to the described importance of comfort described above, material design is an important research topic in the field of textile and clothing engineering. Considerable efforts have been made to interpret tactile attributes with regard to the human senses. In addition, researchers have pointed out in a number of recent studies that the tactile attributes of the material are one of the decisive factors related to the final decision to purchase a product (Takasaki et al., 2020; Tadesse et al., 2019; Salopek Čubrić et al., 2023). In their study, Harpa et al. (2019) focussed on the sensory evaluation of the tactile properties of stretch denim. The authors selected sixteen undergraduate textile students as panellists. This research suggests that the need to feel the fabrics is self-understood for every buyer of clothing items, regardless of whether they have a background in textiles or not. Salopek Čubrić et al. (2019) categorised the evaluators into seven demographic groups based on age, gender and education level. The authors noted the gender discrepancy between the results obtained for different attributes. This observation was particularly pronounced for the attributes of smoothness and softness, within the group of male evaluators. Dabolina et al. evaluated panellists performing different jobs in the factory that produces fibres to predict the average preferences of a larger consumer group. The outcomes of the study showed that the stiffness of the fabric was the easiest to predict among the set of different attributes. Ishikawa et al. attempted to clarify the differences in the perception of handiness of fabrics among 20 Japanese and 20 Chinese people. According to the study, Chinese people have stronger preferences for fabrics than Japanese people. Compared to the Chinese, the Japanese evaluated the hand feel of fabrics more carefully, including distinguishing different fabric attributes such as fibre and yarn thickness and density. The authors therefore claim that nationality can influence fabric hand perceptions.

EXPERIMENTAL

The aim of this study is to determine the effects of material engineering (in terms of different compositional and structural designs of the materials used for the manufacture of sportswear) on human perception of the tactile attributes of the material, i.e. on the fabric hand only. In order to compare the outcomes of the material evaluation conducted by recruited evaluators, additional instrumental tests have been conducted and placed in the context of the subjective evaluation results.

DESIGNED MATERIALS

For the study, a series of 14 materials were selected from the market that are representative for the production of football sportswear. The selected materials differ in their yarn composition, which was either 100% standard polyester or 100% recycled polyester. In addition, some of the materials were plated with elastane yarn to increase the elasticity of the material and the body fit. The details of the materials, including the sample ID, material composition, and mass per unit area are listed in Table 1. The fabric composition was determined by the manufacturer. The structure of the fabric was determined by the authors of this paper, and the mass per unit area was determined by weighing 10 samples of each material (size 1 dm^2) on the analytical balance.

Table 1. Overview of the investigated materials.

Sample ID	Fabric Composition	Fabric Structure	Mass per Unit Area, g/m^2
F1	100% polyester	Double jersey mesh	105
F2	100% polyester	Double jersey mesh	152
F3	100% polyester	Double jersey mesh	192
F4	100% polyester	Double jersey plated mesh	157
F5	100% polyester	Plated double jersey	136
F6	100% polyester	Double jersey mesh	155
F7	100% polyester	Interlock	151
F8	100% polyester	Double jersey mesh	145
F9	91% polyester + 9% elastane	Single jersey	178
F10	92% polyester + 8% elastane	Single jersey	197
F11	84% polyester + 16% elastane	Single jersey	180
F12	87% polyester + 13% elastane	Single jersey	141
F13	100% polyester, recycled yarn	Single jersey	130
F14	100% polyester, recycled yarn	Single jersey	185

EVALUATION OF ROUGHNESS WITH PARTICIPATION OF EVALUATORS

To analyse the roughness of the 14 selected materials, 25 evaluators aged 20–25 years with an average age of 23 years were recruited. The study in which the subjects participated was conducted in accordance with the approval of the Ethics Committee of the University of Zagreb, Faculty of Textile Technology. Before the evaluation began, the subjects were familiarised with the purpose of the test, and the test method was explained to them. The designed materials were cut to a size of 100x100 mm and presented to each evaluator for evaluation of roughness. During the evaluation, the evaluators could see the materials (i.e. the test was not blind). The evaluators were then asked to give their rating of roughness on a smoothness-roughness scale (S-R scale) of 1-7. On the S-R scale, a score of 7 indicates the highest roughness of the material. Figure 1 shows how the material was manipulated during the evaluation.

Figure 1: Material manipulation during evaluation.

OBJECTIVE EVALUATION OF ROUGHNESS

The device used to determine the roughness of the material was the PCE RT-2000 roughness tester. The data collected by the device is determined from a graph composed of the measured length of the sample in mm and the peaks and valleys of the sample in μm. The arithmetic mean deviation of assessed profile (R_a) is the parameter that is most useful and is often used to analyse the surface structure. The absolute values of the profile variations Z_1, Z_2, ... Z_n from the mean line in the evaluation length are mathematically averaged to obtain this number. R_a is the widely accepted and applied roughness parameter and is generally used to assess surface roughness. It is the absolute value of the profile changes in the measurement section's arithmetic mean. R_a is a measurable numerical number that is consistently smaller than R_z determined with the identical roughness profile. R_a is calculated as:

$$R_a = \frac{1}{n} \sum_{i=1}^{n} |Z_i| \tag{1}$$

where n is the number of them and Z_i is related to the ordinate values.

RESULTS AND DISCUSSION

The results of the study include the assessment of roughness on a scale of 1–7 conducted by volunteers and measurements on a roughness tester. The results of the roughness assessment carried out by volunteers are shown in Figure 2. As can be seen from this figure, the average values reported by the evaluators ranged from 1.25 to 5.35, indicating that the evaluators perceived the roughness of the materials to be different. The highest value, i.e. the highest roughness, is recorded for materials F1 and F3, both of which are 100% standard polyester materials. The lowest roughness is perceived for materials F7, F9 and F11, i.e. for the 100% polyester material and the polyester materials with the addition of elastane. As can be seen from Figure 2, the materials made of recycled polyester yarns are perceived as smoother than most materials made of standard polyester yarns.

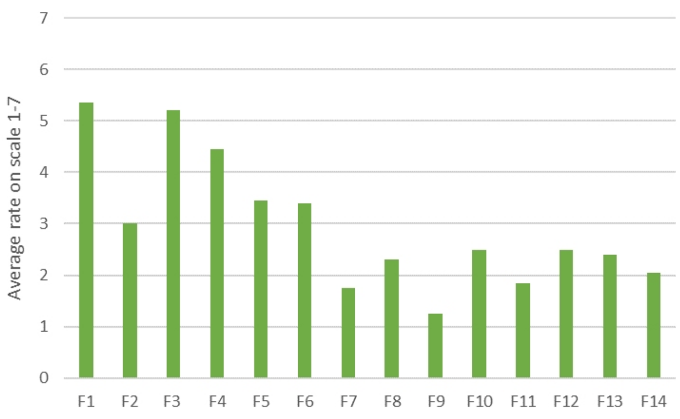

Figure 2: Average rate on the roughness scale 1-7.

From a material engineering point of view, it is important to consider the materials according to their structure (i.e. double jersey vs. interlock vs. single jersey). In this context, it becomes clear that materials produced in double jersey structure are perceived as rougher than interlock and single jersey materials, while the interlock material (F7) is perceived as the second smoothest within the entirety of the designed materials. Within the group of double jersey materials, the roughest materials are F1 and F3, while the smoothest are F2 and F8.

The results of the roughness test with the roughness tester in the horizontal direction of the material are shown in Figures 3 and 4. The mean values of R_a measured for the front side of the materials are in the range of 8.06-20.86 μm (Figure 3), indicating large differences in the measured property between the observed set of materials. On average, the R_a values are lower for the materials produced with the addition of elastane.

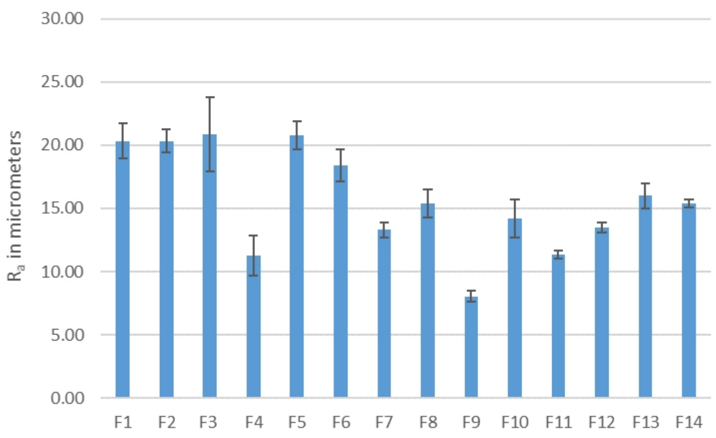

Figure 3: Mean values of R_a measured for the front side of the materials, measured in the horizontal direction of the material.

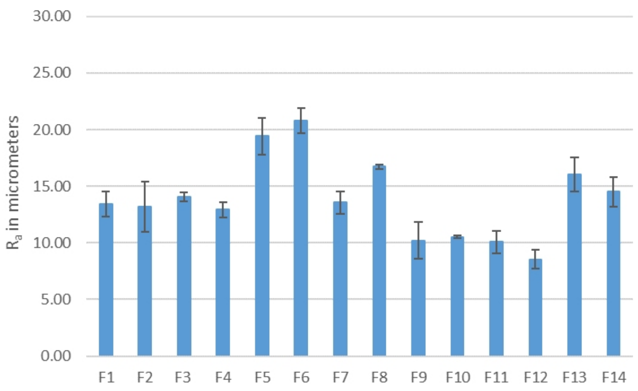

Figure 4: Mean values of R_a measured for the back side of the materials, measured in the horizontal direction of the material.

Mean values of R_a measured for the back side of the materials (Figure 4) are in the range of 8.55-20.82 μm. The highest R_a values were measured for the two materials made of standard polyester and again for the material made of recycled polyester material (F13).

The results of the roughness tests in the vertical direction of the material are shown in Figures 5 and 6. The mean values of R_a measured for the front side of the materials, measured in the vertical direction of the material (Figure 5), are in the range of 6.59-11.13 μm. The R_a values for the measured materials are on average lower than in the horizontal direction of the materials (both on the front and back side) and the differences in the values between 14 materials are less pronounced. Only three materials have the R_a values above 10 μm and this relates to 2 materials made of standard polyester and one made of recycled polyester (all three materials without added elastane component). The mean values of R_a measured for the back side of the materials (measured in the vertical direction of the material) are in the range of 8.80-21.90 μm. The highest R_a values are measured for the two materials made of standard polyester. In contrast to the R_a values measured in the horizontal direction of the material, the R_a values of the recycled polyester materials are lower in the vertical direction of the material.

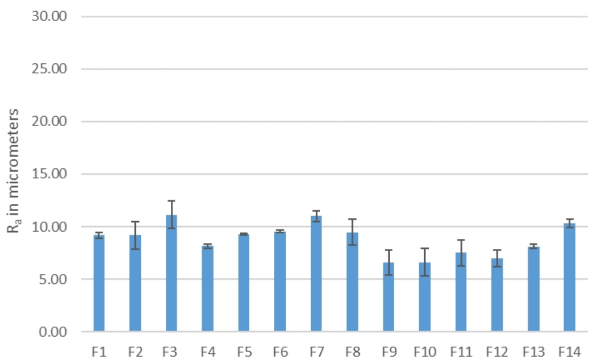

Figure 5: Mean values of R_a measured for the front side of the materials, measured in the vertical direction of the material.

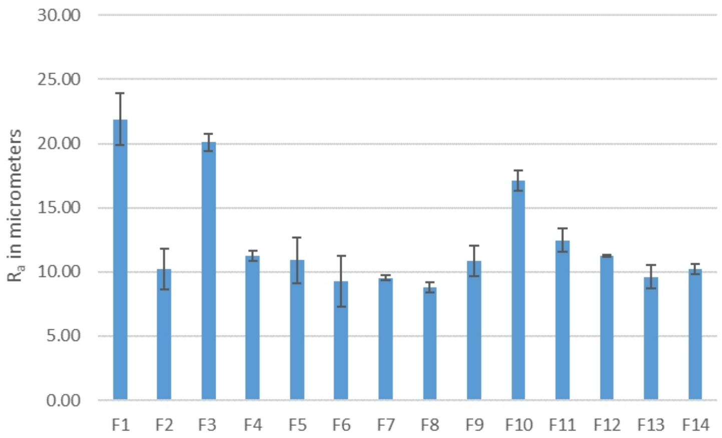

Figure 6: Mean values of R_a measured for the back side of the materials, measured in the vertical direction of the material.

The mean values of R_a, which were determined from the results of the R_a measurement for the front and back side in the horizontal and vertical directions, are shown in Figure 7.

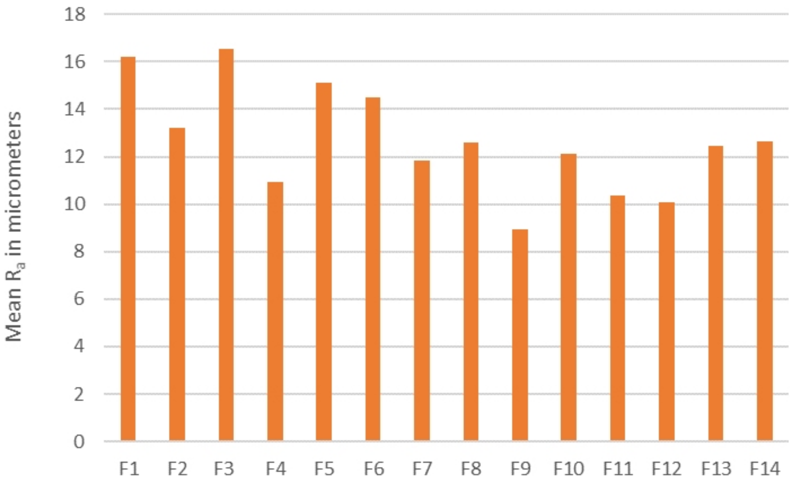

Figure 7: Mean values of R_a determined from all R_a results.

Both the results of the roughness evaluation by volunteers and the results of the mean roughness (Ra value) indicated that materials made of 100 % polyester materials on average have a higher average roughness than those with the addition of elastane. The correlation between the evaluators' ratings (S-R), and mean values of Ra is moderate with a correlation coefficient of 0.651 (Table 2). It is interesting to note that through objective measurements (with a roughness tester), we found that material F9 was the smoothest, and that the evaluators also rated the same material as the smoothest. The same was observed when evaluating the roughness of the material. According to subjective and objective measurements, the roughest material is F1 and F3. This indicates that the rates given by evaluators may be considered as reliable for the observed property of roughness. Furthermore, the results showed that evaluators perceived even greater differences in terms of material roughness between the materials compared to the instrumental method (i.e. compared to the mean Ra value). This suggests that the human factor is an important segment in the evaluation of material attributes. Furthermore, these results highlighted the need for additional efforts in material engineering, as the fact that the differences between materials need to be recognised by consumers at a relatively small level. If the evaluators who participated in this study acted as purchasers/consumers of sportswear, the choice would be directed towards materials made with added elastane in terms of the observed property, whereby recycled materials would not take a back seat compared to standard polyester materials.

Table 2. Correlation between the results of evaluation and instrumental testing.

	S-R	R_a-F-H	R_a-B-H	R_a-F-V	R_a-B-V
R_a-F-H	0.639				
R_a-B-H	0.253	0.583			
R_a-F-V	0.347	0.585	0.565		
R_a-B-V	0.671	0.353	-0.270	0.039	
R_a-mean	0.651	0.879	0.645	0.570	0.411

Marked correlations are significant at $p < 0.050$.

CONCLUSION

The aim of this study was to determine the effect of material engineering on the human perception of the tactile attribute of the material (i.e. the fabric hand), more specifically the fabric roughness. Moreover, this study was focused at the comparison of the outcomes of subjective and objective evaluation of roughness. The results show that the differences between the designed materials in terms of observed attributes is significant, suggesting that the human factor is an important segment in the evaluation of material attributes. This leads to the conclusion that the selection of an unsuitable material from the group of materials analysed should lead to an unsatisfactory comfort level and possibly to a less successful performance of an athlete. The results of the used methods showed a fairly high correlation between the evaluators' ratings and the outcomes of the instrumental measurements. The results of this study can be considered useful for the sportswear market segmentation, and the further development of sportswear targeting specific athlete profiles.

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