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Perceptual responses of (sports-)clothing-body interaction simulating pre- and post-purchase experience

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ABSTRACT

The appreciation of textile products highly depends on a satisfactory 'feel' in fabric-skin contact. The question arising is whether the haptic interpretation of a garment (by hand) is comparable to a feeling produced when it is donned or used in its intended application. Sports T-shirts made from three different fiber types (CO, PES I, PES II) were studied in a pre- and post-purchase scenario by exposing 20 female participants to a hand, a donning (pre-purchase) and running evaluation (post-purchase) in 22 °C and 50% relative humidity (RH). Objective measurements such as skin temperatures, heart rate, body sweat loss, and sweat absorption of the garments were recorded. Subjective data was collected during the fabric hand and the donning evaluation as well as within the running protocol after 5 min, 20 min, and 5 min of cool down. Perceptual responses to 12 hand-/skin-feel descriptors (e.g., rough, smooth) were rated on a scale from 0 (not at all) to 10 (completely) and a feeling of discomfort was given. No significant differences between a hand and a donning evaluation were found in the rating of the sensations. The hand evaluation provided sufficient information for a comfort response to garment wear. The pre- and post-purchase comparison found a significantly lower perception of the feeling of roughness whilst running with the CO shirt and smoothness during running in PES II. The stickiness and comfort perception increased significantly in the post-purchase wear trial. Hence, moisture on the skin provoked through running influences comfort characteristics as well as the perception on haptic cues in t-shirts. Especially surface related haptic characteristics e.g., roughness and smoothness, are reduced.

Keywords
clothing-body interaction,
textiles,
perception,
sportswear,
purchase process

1 Introduction

Within the purchase process of sports textiles, the feel of garments has been identified as a crucial parameter, especially for female consumers [1]. Also, Li et al. [2] found that the appreciation of textile products depends on a satisfactory 'feel' in the area of fabric – skin contact. The question arising is whether the haptic interpretation of a garment (by hand) is comparable to a feeling produced when it is donned, or when it is used during its intended application. The connection between the first interaction of the consumer with the product and the final situation of use is important to understand to improve the prediction of a comfortable feel. While efforts have been made to define fabrics' comfort using physical measurements, it is ultimately only possible to be evaluated in a subjective way. Wear comfort is a complex phenomenon, which is greatly affected by what humans feel [3]. Experiencing comfort is the ability of sensing and recognizing a state of being, however, it is not based on an individual identifiable sense organ like the basic five senses. Rather, it is associated with a satisfactory and pleasant condition of the body [4]. Physiological (e.g., moisture management) and psychological (e.g., design) characteristics as well as the 'feel' of clothing contribute individually but equally interact to the acceptability of garments worn next-to-skin. To understand these factors it is important to understand the overall judgment of clothing comfort [2].

In a store-like setting, garments hang on a rack or lay on a shelf. During the pre-purchase process, garments are evaluated by using the hands at a first instance. If expectations on the garments are fulfilled by e.g., the feel of the fabric, design, color, brand, etc., an evaluation on the body will follow in the changing room. Eckman et al. [5] investigated the point-of-purchase decision process and concluded it consists of two stages: decision to try on (interest) and actual trial in the dressing room (trial). During the interest stage color, pattern, style, as well as fibers and fabric, attract consumers initially and lead to a first selection of items to try on. During the later stage (trial), the garment is reassessed on the body in the changing room. Important factors contributing are styling, color, pattern, fit, and appearance. The information collected during the two stages will be weighed together to determine a final decision to reject or buy [5]. During the pre-purchase phase, consumers assess products, not only from functional aspects such as price and quality but also in terms of emotional value and social consequences (e.g., what the product communicates to others). Chi and Kilduff [6] conclude that if a product can deliver certain desired values for the consumers, there would be a greater willingness to buy or recommend the product as well as greater satisfaction with it in the post-purchase stage [6]. The post-purchase experience is highly dependent on meeting consumer needs at the level of product performance. The evaluation results will lead to satisfaction or dissatisfaction [7,8]. Worland et al. [9] investigated the pre- and post-purchase apparel satisfaction of female skiers and snowboarders and found that respondents were (very) satisfied with almost all functional (e.g., comfort, fit, care), expressive (e.g., attractiveness, brand name) and aesthetic (e.g., style, color, design) attributes pre-purchase, however, they rated them lower when asked for post-purchase satisfaction. The results show that there can be a mismatch between pre- and post-purchase perception. According to Chae et al. [7] comfort is identified as one of the most important attributes for women to achieve satisfaction before and after the purchase of tennis apparel. Evaluating consumer pre-purchases can help to gain a better understanding of consumers' purchase decision processes [7].

Tactile comfort in textiles has been highly researched using fabric swatches [10-14], however, the translation of a fabric hand sensation to the sensations experienced when a garment is worn and whilst the garment is performing in end-use conditions is missing. Therefore, this study aims to explore a hand- and a donning perception of running t-shirts (pre-purchase scenario) as well as a dynamic wear trial (post-purchase scenario). The following research questions were defined:

RQ_1: Is there a difference in the evaluation of garments by hand (first instance in a store) or by donning (changing room) in a pre-purchase process?

RQ_2: How does the garment feeling change during actual exercise (post-purchase)?

2 Methods

2.1 Participants

Twenty active females were invited to take part in the study (age: (29 ± 6) years, height: (168.3 ± 5.6) cm, body mass: (61.6 ± 7.6) kg, body fat percentage: (21.7 ± 4.4) %). Participants were required not to have any skin conditions and comfortably run a minimum of 5 km. The running pace in the trial was set according to the participants' identified comfortable 5 km running pace and resulted in an average of (10 ± 1) km/h with a range of 7.5 km/h to 11 km/h. Participants were informed about the general purpose and procedure by written and oral information before obtaining informed consent. The experimental protocol was granted ethical approval by the Human Research Ethics Committee at Loughborough University (Project-ID 7827).

2.2 T-shirt specification

The garment selection was based on eliciting different haptic sensations, to cover a range of haptic attributes (e.g., rough, smooth, lightweight). As commonly used in sports garments, two 100% recycled white polyester (PES) fabrics (PES I, PES II) and one 100% white cotton fabric (CO) were selected to make t-shirts using the same fit pattern (regular fit). A picture of the test garments is provided in Fig. 1. Fabric specifications are shown in Table 1.

Table 1. Fabric specifications. Textile tests followed appropriate standards (Weight EN 12127:1998; Wicking and Evaporation GB/T21655.1-2008; Drying Time ISO 11092; Total Heat Loss ASTM F1868-17 part c).

	Composition	Construction	Areal weight (g/m^2)	Wicking (cm/(30 min))	Evaporation rate (g/h)	Drying time (min)	Total heat loss (W/m^2)
Cotton	100% CO	Single Jersey	160	14.2	0.17	17.1	652.2
Polyester I	100% PES I	Single Jersey	150	6.9	0.21	7.5	844.5
Polyester II	100% PES II	Double Knit	146	8.8	0.26	7.3	785.8

CO **PES I** **PES II**

Figure 1 Regular fitted test T-shirts.

Small and medium-sized t-shirts were included in the study. To ensure appropriate sizing between participants, measurements of participants' waist circumference and shoulder width were taken. The waist circumference was measured according to Raccuglia et al. [15] horizontally at waist level (where the smallest abdominal circumference occurs), while the person was standing upright with the arms held slightly away from the side of the body. Participants who were in the range of 36.5 cm – 40 cm shoulder width and 62.5 cm – 75 cm waist circumference wore a small-sized shirt and participants in the range of 38 cm – 43 cm shoulder width and 70 cm – 80.5 cm waist circumference received a medium-sized shirt, respectively. The main selection criterion for the appropriate size was that the participants did not feel restricted in any way. In cases in which the participant was meant to wear a larger size (based on the above criterion) but would prefer to wear, and generally buy, the smaller version, they received their preferred choice i.e., the smaller version. The t-shirts were laundered according to ISO 6330 2012 (washing machine type A, procedure no. 3N, reference detergent 3, line-dry) three times before the trial and after each trial session, to standardize the condition of use. The T-shirts were conditioned in the climatic chamber 24 hours before the trial.

2.3 Perceptual scales and attributes

Ordinal and interval scales were used to assess the haptic perception of the garments. A previously validated magnitude scale was used to quantify 12 subjective descriptors which are discernible as part of the hand-feel of fabrics (rough, smooth, natural, synthetic, warm, cold, scratchy, breathable, heavy, lightweight, stretchable, and sticky) [14]. Participants were able to rank fabric attributes on the scale from 0 (not at all) to 10 (completely). The order of the attributes was not randomized to assure that the thermal properties of the fabrics (cold/warm) were asked at the same time points. A (dis)comfort scale adapted from Raccuglia et al. [16] was used to gain information regarding the person's discomfort caused through interaction with the shirt e.g. while sweating. Participants were able to select their discomfort rating from 1 (comfortable) to 7 (very uncomfortable), whilst 3 categorized a slightly uncomfortable perception and 5 an uncomfortable perception. Participants were instructed on how to use the perceptual scales.

2.4 Experimental procedure

All conditions were carried out in a climatic-controlled chamber set at an ambient temperature of 22 °C, 50% RH, and air velocity < 0.05 m/s, respectively. The environmental condition was chosen to enable comfort during rest and to produce sweating during exercise (according to pilot studies). The experimental procedure consisted of two parts:

I) Hand and donning evaluation (pre-purchase scenario)

During the fabric hand evaluation, garments were hanging in counterbalanced order on a rack. Participants were asked to take one at a time whilst perceiving the haptic properties of each material to simulate an in-store scenario (Fig. 2a). An evaluation of the garments on the magnitude scale according to the list of attributes regarding tactile sensations, was performed and (wear) discomfort was judged. Once the fabric hand evaluation was completed, participants were asked to don each t-shirt starting again with the first t-shirt of the hand evaluation (followed by the same order) and perform the same ratings based solely on how the shirt felt on the upper body.

II) Dynamic wear trial (post-purchase scenario)

A dynamic wear trial of each running t-shirt (counterbalanced order) consisted of performing a 20 min self-paced run on the treadmill with 5 min of cool down (standing position) (Fig. 2b). Participants were asked to rate selected haptic attributes after 5 min running (running I), after 20 min (running II) and after the cool-down phase. Running I allowed a perceptual rating of the dry fabric moving across the skin whereas the rating in running II involved the interaction with sweat. The cool-down phase was the last time where participants were asked to rate the selected haptic attributes. The dynamic wear trial was repeated for the second and third t-shirt in another trial. Participants performed three visits on different days, separated by at least 24 h of rest at the same time of the day ± 1 hour to minimize circadian variation. On the first visit, all participants performed the hand and donning evaluation followed by one dynamic wear trial with one of the t-shirts. The second and third visit involved only the dynamic wear trial each with the evaluation of the remaining two t-shirts. Finally, a ranking of the shirts regarding the likelihood of purchase was performed. On each trial day, they were asked to wear the same set of sports shorts, socks, a comfortable sports bra they would use for running, and running shoes. Upon arrival participants acclimatized in the climatic chamber for 15 min. Prior to data collection, participants confirmed their health status on a questionnaire and gave consent to participate after being informed about the procedures and risks involved in the study. Anthropometric data such as height, shoulder width, waist circumference and body composition via bio-electrical impedance (Body composition analyzer, Tanita, MC-780MA) were recorded.

a b

Figure 2 (a) Hand/donning evaluation (pre-purchase scenario); (b) dynamic wear trial (post-purchase scenario).

2.4.1 Objective measurements

Skin temperature, heart rate (HR), and sweat amount were recorded to gather objective data on parameters affecting comfort. The mass of the t-shirts was measured pre- and post-trial using a balance (Kern & Sohn GmbH, Balingen, Germany) accurate to 0.01 g. The mass of sweat was calculated as the difference in garment mass measured before and after exercise. The total body mass loss was calculated as the difference in pre and post weight of the participants. Wrist-based HR measurements were obtained throughout the running procedure on the treadmill with a Garmin Forerunner 945 (Garmin Ltd., Kansas, USA). Skin temperature measurements were obtained throughout the entire protocol at four sites: upper arm, chest, thigh, and calf using Wireless Climate Network (WCN2) sensors (University of Applied Science, Kaiserslautern, Germany). Mean skin temperature (T_{skin}) was calculated as a weighted average of the four skin sites using the formula (1) [17].

$$T_{skin} = 0.3 * T_{Upper\ arm} + 0.3 * T_{Chest} + 0.2 * T_{Thigh} + 0.2 * T_{Calf} \quad (1)$$

2.5 Statistical analysis

Differences in interpretation of the garments evaluated by hand, by donning, within running I + II and cool-down were assessed individually for each T-shirt using a Kruskal-Wallis H test. Differences between the materials in the perceptual ratings, in the distribution of total sweat amount, and distribution of temperature across activity were further assessed by another Kruskal-Wallis H test each. This nonparametric alternative to the ANOVA was used since the dataset deviated from a normal distribution; Bonferroni correction for multiple tests was applied to counteract a multiple comparisons problem. Statistical analysis was performed using IBM SPSS Statistics 27 (IBM, USA). Subjective evaluation ratings were reported as medians together with the 25th and 75th percentile; objective data were reported as means ± standard deviation (SD). A probability level of $p < 0.05$ was defined as the threshold for significance.

3 Results

3.1 Objective measurements

Mean (± SD) environmental conditions for the experimental trial were (22.2 ± 0.3) °C temperature and (48.7 ± 1.1) % RH. No difference in mean skin temperature was noticeable between the two polyester and the cotton t-shirt, respectively (Fig. 3). During exercise, after an initial drop, skin temperature increased significantly from the hand-feel phase with an average skin temperature value of (31.2 ± 0.6) °C to the cool-down phase with a value of (32.8 ± 0.9) °C. No significant differences were found in the heart rate within the running trial of the cotton and polyester shirts and between the shirts.

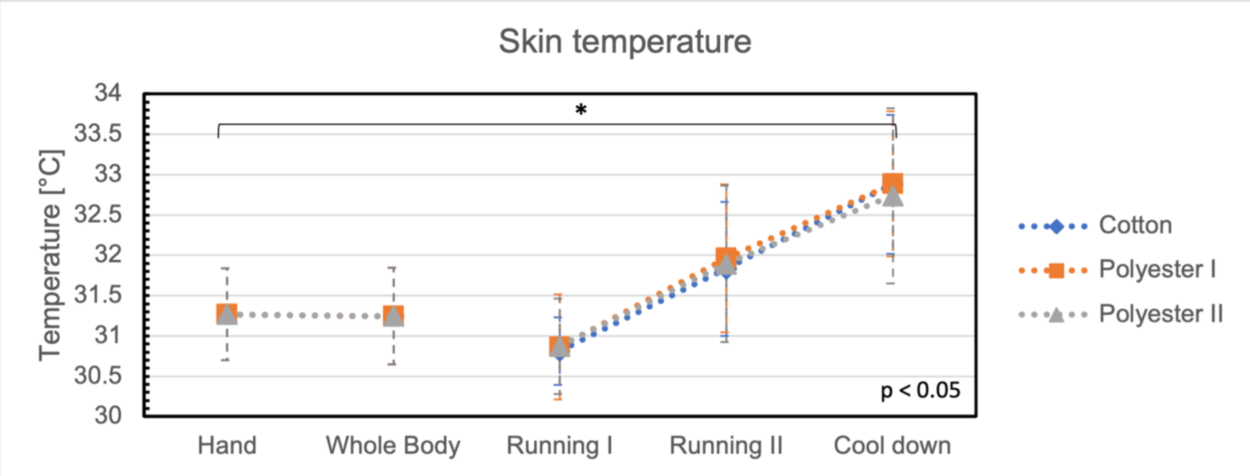

*Figure 3 Mean (± SD) skin temperature calculated from chest, upper arm, thigh, and calf. * indicates a significant difference.*

Significant differences in sweat uptake were observed between the cotton and polyester I t-shirt. The cotton fabric significantly absorbed the most sweat with a mean of (6.49 ± 4.88) g. Polyester I absorbed the least amount of sweat with a mean of (3.53 ± 3.52) g. Generally, there were large standard deviations in all three groups. The total body mass loss showed no significant differences between the T-shirts and was consistent between participants (Table 2).

Table 2. Mean (± SD) garment sweat uptake & mean (± SD) total body mass loss.

	Total sweat uptake (g)			Total body mass loss (kg)		
Cotton	6.49*	±	4.88	0.26	±	0.11
Polyester I	3.53*	±	3.52	0.24	±	0.09
Polyester II	4.52	±	4.30	0.23	±	0.09

3.2 Evaluation of garments by hand, by donning (pre-purchase) and during running (post-purchase)

The study explored the haptic hand-feel perception of sports garments in relation to body perception in a static (pre-purchase scenario) and dynamic wear trial (post-purchase scenario). A total of 12 haptic attributes were assessed in one cotton and two polyester test t-shirts. Only three out of 12 attributes were significantly different in the running evaluation in comparison to the pre-purchase evaluation. The haptic attributes where perceptual ratings significantly changed were rough, smooth, and sticky. The following figures show the statistical differences of rough and smooth as an example of the haptic attributes in the cotton, polyester I and polyester II test t-shirt. Medians together with the 1st and 3rd quartile are displayed in the figures.

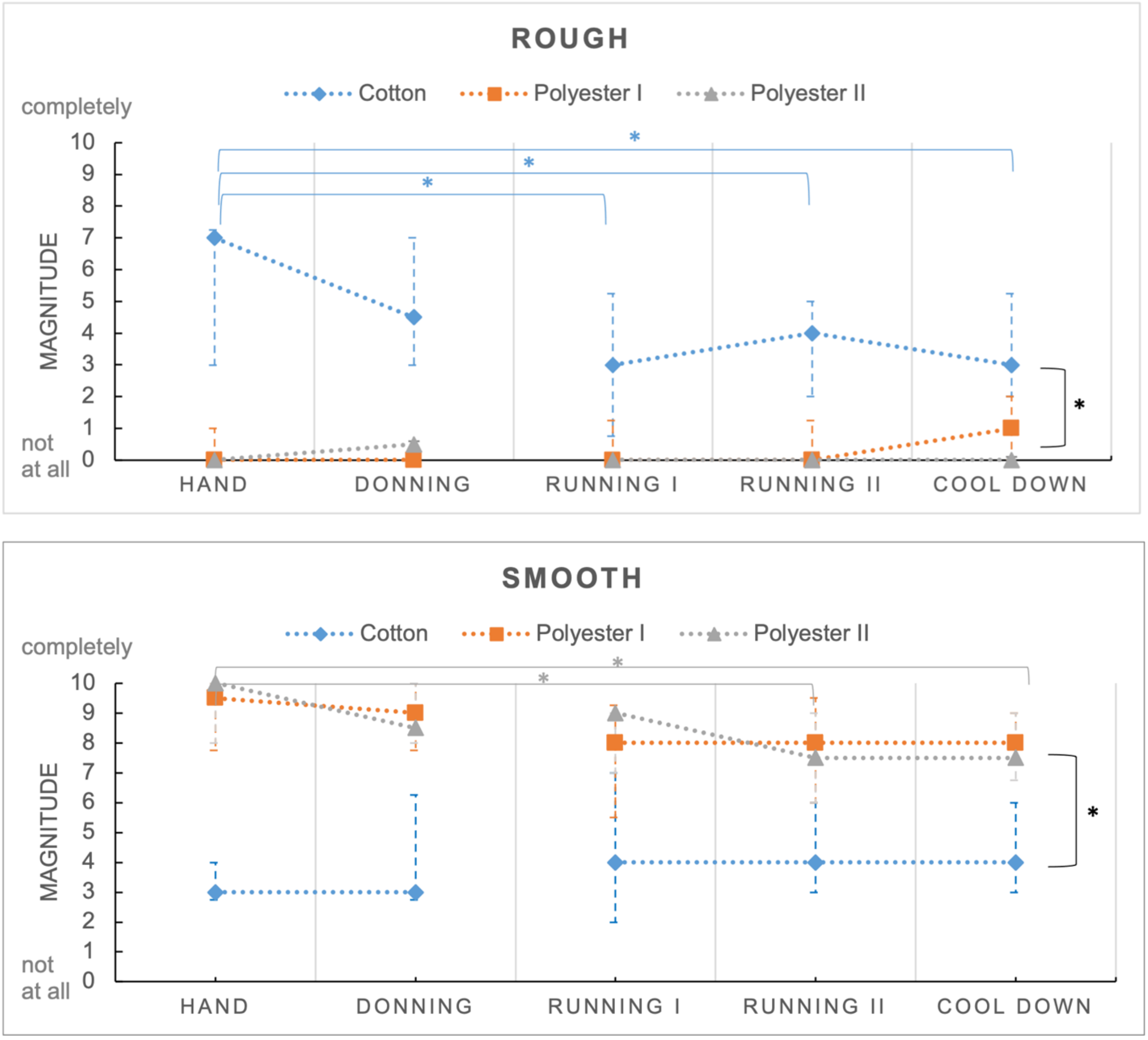

Figure 4 Perception of rough and smooth in the pre- and post-purchase scenario for the three test garments. Medians together with the 25th and 75th percentile are shown.

The perception of roughness decreased significantly whilst running with the cotton shirt. The roughness perception was significantly lower in phase running I ($p = 0.026$), running II ($p = 0.032$) and cool down ($p = 0.024$). Similarly, the perception of smoothness decreased significantly, during running with polyester II from a hand-feel perception to running II ($p = 0.025$) and cool down ($p = 0.03$) (Fig. 4).

The perception of stickiness and discomfort ratings increased significantly from pre- to post-purchase (Figures 5 & 6). A significant increase in the discomfort rating was found between the hand evaluation (pre-purchase) and the cool down phase in the polyester II ($p = 0.041$) and between the donning evaluation (pre-purchase) and the cool down phase in the cotton t-shirt ($p = 0.02$). Cotton was further perceived as the least comfortable material during the running protocol (running I CO-PES I: $p = 0.011$; running II CO-PES I $p = 0.025$; CO-PES II $p = 0.003$; cool down: CO-PES II: $p = 0.011$).

No significant differences were found in the perception of warm/cold, natural/synthetic, heavy/lightweight, scratchy, stretchable, and breathable between the pre- or post-purchase scenario. The cotton fabric was typically rated significantly different (worse) in comparison to either one or both polyester materials, whereas the two polyester materials did not differ significantly. No significant differences between the materials were found in the hand evaluation in the attribute warm, in the attribute sticky until the beginning of the running scenario (running I), and in the cool down phase in the attribute cold. The PES II shirt was the most preferred choice for a purchase intention.

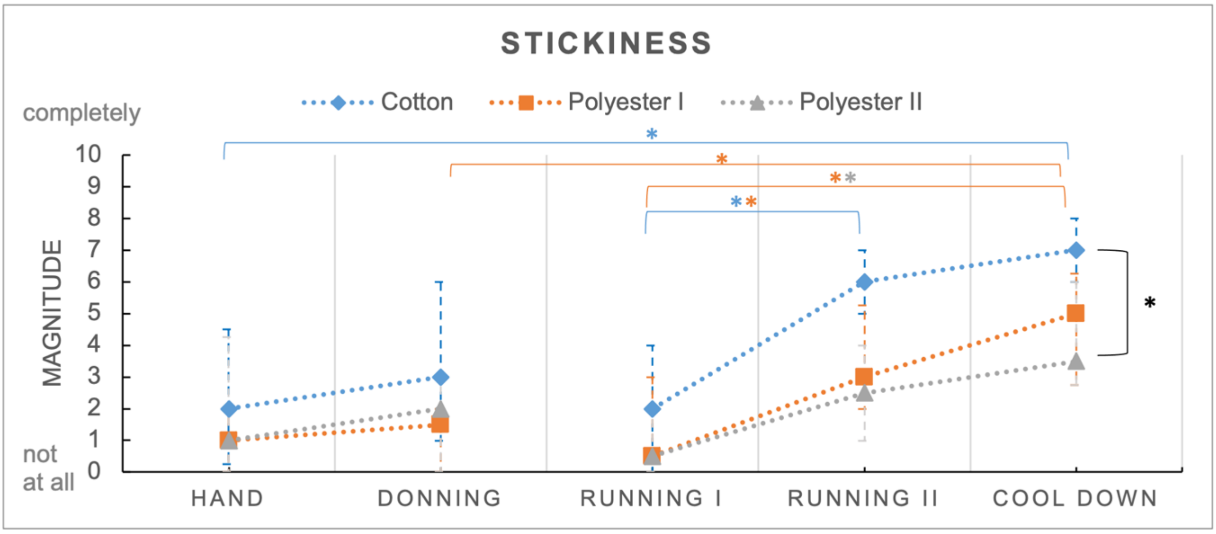

Figure 5: Perception of stickiness in the pre- and post-purchase scenario for the three test garments. Medians together with the 25th and 75th percentile are shown.

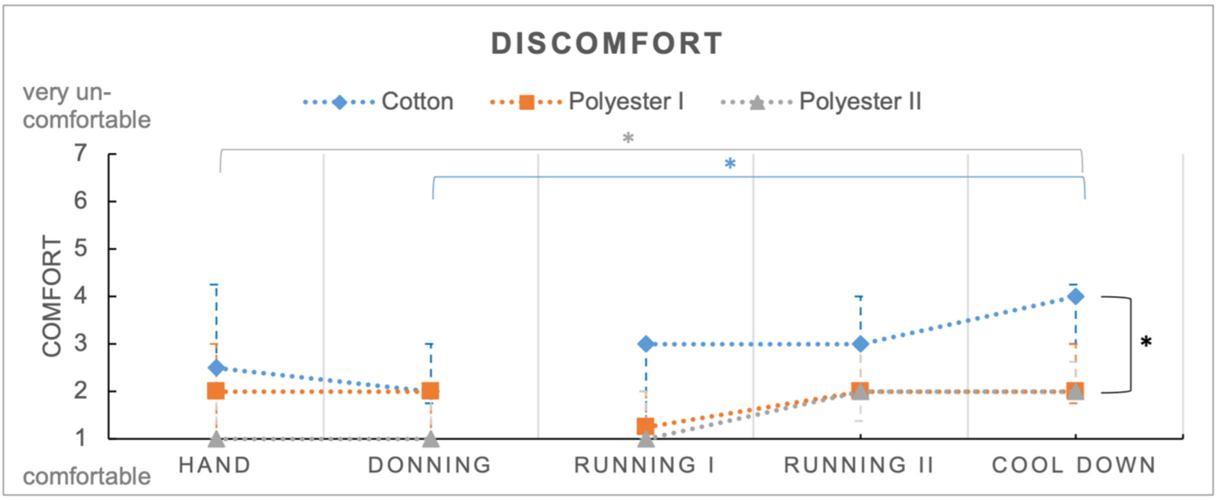

Figure 6 Perception of discomfort in the pre- and post-purchase scenario for the three test garments. Medians together with the 25th and 75th percentile are shown.

4 Discussion

Comfort is very important for next-to-skin garments such as t-shirts. A state of comfort can only be achieved when the interactions between a range of psychological, physiological and physical factors have taken place in a satisfactory manner [18]. According to Eckman et al. [5], visual criteria have the greatest impact on the selection of garments for trial in the dressing room. However, intrinsic criteria such as fiber and fabric were found to have an impact on clothing evaluation and during the decision-making process. During the present study perceptual data of the feel of sports t-shirts were assessed as well as data concerning changes in skin temperature, heart rate, sweat uptake, and body mass loss. The aim was to determine perceptual differences in a pre- (hand and donning evaluation) and post-purchase (running evaluation) scenario.

4.1 Objective measurements

No significant differences were found in T_{skin} and HR between the shirts. However, mean skin temperature changed over time as the exercise progressed and a significant increase in temperature was observed from the hand evaluation/running I to cool down. According to Markee et al. [19], skin temperature is a significant determinant of perceived thermal comfort. Looking at the perception of discomfort by the end of the running period, it is noticeable that the feeling of discomfort significantly increased with the increase in skin temperature (in CO and PES II). Despite equal physiological responses (T_{skin}, HR, total weight loss) between the shirts, perceptual differences between the garments were found (e.g., warm/cold, sticky, breathability in the cotton fabric). It indicates that observed differences in the perception of garments are based on subjective perception and sweat uptake of the shirts. The cotton fabric held the most sweat (6.5 g) and absorbed almost twice as much sweat as polyester I (3.5 g). Sportswear fabrics need to have the ability to move moisture away from the surface of the skin to the surface of the fabric to evaporate to the external environment (wicking) and enhance wear comfort [20]. The hygroscopic cotton material had the best ability of the three fabrics to absorb water (wicking property 14.2 cm/(30 min)), but the worst ability to evaporate liquid/sweat (0.17 g/h) or dry (17.1 min). This explains that the total sweat uptake of the cotton material was significantly the most likely leading to the higher discomfort ratings. Participants further reported they feel the stickiest and would not use the cotton fabric for running. Cotton fabrics have the highest ability to absorb water and are known to cling against the skin surface when wet [19]. Both polyester materials had lower wicking properties (6.9 cm/30min PES I; 8.8 cm/30min PES II, respectively) compared to cotton, but a higher ability to evaporate water (0.21 g/h PES I; 0.26 g/h PES II) and dry more than twice as fast (7.5 min PES I; 7.3 min PES II) which are the most likely causes for the hydrophobic polyester fiber supporting lower discomfort ratings as well as a lower stickiness perception in comparison to cotton.

4.2 Evaluation of garments by hand, donning (pre-purchase) and during running (post-purchase)

The pre-purchase process was divided into two stages: first, the decision to try on (interest stage), where the hand-feel of the garment was a crucial parameter, and second, the trial in the dressing room, where a donning evaluation of the garment took place. The post-purchase scenario looked at an evaluation of the garments in their end-use condition, in this case, a running trial.

The sensations derived from handling and donning the garment are overall very much comparable. No significant differences were found in the comparison of the hand-feel and donning evaluation in all attributes. This means that the evaluation of garments by hand when touched elicits the same perceptual ratings and, therefore, sensations as possibly in a changing room. I.e., an overall evaluation of haptic sensations in a t-shirt can be assessed solely by handling.

The pre-purchase assessment was compared to the post-purchase assessment. Significant differences were found in the perception of roughness, smoothness, and stickiness. The perception of roughness as well as smoothness decreased significantly during running within the cotton shirt and the polyester II, respectively. Fundamental studies in the field have shown that the perception of roughness and texture increases with an increase in skin wetness. Gwosdow et al. [21] found that moisture on the skin surface enhances a perception of roughness and decreases the acceptability of clothing worn in especially hot environments. As force and skin wetness increased, fabrics were perceived as more textured (rougher) and less pleasant. Despite literature findings that the roughness perception increases with an increase in moisture level, the findings show that the cotton t-shirts' perception of roughness decreased significantly between the pre- and post-purchase scenario, while its smoothness did not change significantly. There could have been a level of habituation to the perception of roughness whilst the running activity could have distracted participants from the perceived magnitude of this hand-feel characteristic. A reason for the altered roughness perception of cotton could be explained by the drying mechanism of the fabrics. Tumble-dried garments usually feel smoother and softer than line-dried ones. A tumbled-dried cotton t-shirt could have had a lower roughness perceptual value in the hand-feel assessment; however, line drying was chosen to prevent fibre or fabric damage. Furthermore, the surface of the fabric could have affected haptic sensations since sensory receptors in the skin surface are triggered by the contact of the fabric surface with the skin. The touch receptors convey tactile sensations associated with softness, stiffness, and stickiness [22]. Once participants started sweating (the surface of) the fabric became wet and haptic sensations which were present in a dry state changed. A wet film covering the fibers of the cotton and polyester materials could have influenced the haptic properties and provoked a feeling of lower roughness (cotton) and lower smoothness (polyester II) at the same time. Additionally, the cotton material due to its hygroscopic nature trapped the most moisture by highest wicking and lowest evaporation properties which influenced the roughness perception on the material.

The feeling of stickiness increased significantly and possibly also had an impact on the smoothness and roughness ratings. This is comparable to Laing and Ingham [23] who also found that participants rated garments as clammier following a (second) exercise period and that perceptual changes occurred on the prickly-smooth and the cool-warm scale. Further, Li et al. [2] determined preferences of t-shirts by the hand-feel and whilst wearing them and found that sensation of softness and hardness changed with the accumulation of moisture on the skin. Equally, earlier work by Gerrett et al. [24] and Ouzzahra et al. [25] has shown that e.g., thermal sensitivity is reduced in exercise in both males and females, which is possibly another explanation of reduced sensations.

There were no significant differences in the perception of warm and cold pre- and post-purchase. However, the perception of warmth first increased slightly whilst running until running II and decreased again in the cool down phase. The opposite occurred for the feeling of cold. Once the participants started running, movement of the limbs increased flow of air across them, which supports heat loss through convection and mitigates participants increased perception of warmth from the start. During ongoing sporting activities, convection is no longer sufficient to maintain the body at a constant temperature and heat must be extracted from the body via sweat evaporation. By the end of the run participant's skin temperature and perception of warmth increased and sweat production started. In the cool down phase, no further heat was created by muscle activity; however, energy was still drawn from the body by the evaporative mechanism. Therefore, the perception of warm drops again and the feeling of cold becomes dominant.

The perception of heavy and lightweight did not show any significant difference between pre- and post-purchase. A trend of a decrease in the sensation of heaviness was observed from the hand evaluation to donning evaluation and an increase from running I to running II. Evaluating the weight of the fabrics by hand elicits a higher rating than when the garment is on the person's body. The small increase in the heaviness perception during running can be explained due to the sweat uptake of the garments and increased contact points of the shirt with the body.

No significant differences were found in the perception of breathable, scratchy, stretchable, natural, and synthetic between the different phases of the pre- and post-purchase scenario. Most of the tactile sensations did not change with time during exercise, however, a significant difference was found between the cotton and the polyester shirts. The comparison between the three fabric types found that cotton was significantly perceived as the most natural (least synthetic), the roughest (least smooth), the warmest (least cold), the heaviest (least lightweight), the scratchiest, least stretchable, least breathable, most sticky, and least comfortable fabric in at least two conditions. The total heat loss (THL) value of cotton (652 W/m^2) compared to polyester (845 W/m^2 PES I; 786 W/m^2 PES II) could be a reason for the significant difference in the perception of warm/cold and breathable. The lower the total heat loss of a material the more heat can be trapped within the fabric, the higher the THL the more heat will be lost due to convection/conduction and evaporation. The latter is characteristic for more breathable fabrics. Polyester II was significantly the most lightweight garment (perceived) which links to the weight of the material, though differences were below 10%.

The discomfort rating of the assessed fabrics significantly increased once sweating occurred (from pre-purchase to cool down phase). This is in accordance with Hollies et al. [26], who found that clothing is only sensed as uncomfortable if there is mild to heavy sweating combined with a warming or chilling temperature and a change in activity. For normal wear without heavy sweating, differences between garments are quite small. Reasons for the rise in discomfort ratings are the different abilities of clothing to handle increased sweating and moisture levels at the skin-clothing interface as well as the number of contact points with the skin [26]. According to Mecheels [27] and Markee et al. [19], clothing is more comfortable if the number of contact points between fabric and skin surface is reduced and the skin is dry.

5 Conclusion and outlook

Comfort has been one of the most important attributes in how consumers perceive the acceptability and desirability of functional apparel products in the markets [20]. The clothing comfort concept is a complex subjective sensation related to interactions of fabrics that come in contact with the body and are influenced by climatic, human physiological and psychological factors [20]. In this study quantitative (e.g., T_{skin}, sweat uptake) and qualitative (rating of haptic descriptors) characteristics were collected to evaluate clothing comfort. This research was designed to assess not only the responses to garments by hand and donning, but to determine if perceptible differences in tactile responses occur during and after moderate exercise.

No significant differences were found between a hand and a donning evaluation of tactile characteristics in running t-shirts. The human tactile sensation provided similar responses in the two assessments. Significant perceptual differences were found between the pre- and post-purchase scenario in the perception of roughness, smoothness, and stickiness. With the accumulation of moisture on the skin, haptic sensations such as roughness and smoothness changed, more precisely decreased with a significant increase in the perception of stickiness and discomfort.

Wearers preferred smooth, lightweight, and breathable fabrics in neutral environmental conditions (22 °C, 50% RH). The cotton fabric was generally perceived as less comfortable, rougher, less breathable, heavier, etc. than the polyester materials.

Considering the multifactorial nature of wear comfort, the data of this study are a valuable tool for a holistic approach in the environment-body-clothing interaction. Perceptual responses in combination with physiological changes are crucial to gain knowledge of a post-purchase product experience since appropriate information are stored in the consumers' brain ready to influence a next purchase action.

Different fabrics than the ones used here could influence human tactile response in more extreme environments when thermal or moisture absorption properties of fabrics would impact the role of comfort even more. Further studies could include different environmental conditions and a wider variety of fabrics.

Author Contributions

J. Wilfling: conceptualization, methodology, formal analysis, investigation, writing – original draft preparation; G. Havenith: supervision, visualization, writing – review and editing; M. Raccuglia: supervision; S. Hodder: supervision; writing – review and editing. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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