Comfort in clothing – Determining the critical factors

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Abstract Comfort is often considered in relation to a single factor causing discomfort, be it environmental, physical, physiological or perceptual. But rarely does one factor actually fully influence how comfortable an individual feels. Even within the clothing system numerous factors; fit, material, design, etc, can affect an individual's comfort perception. Currently the understanding of the impact of individual fabric properties on wear comfort is limited. This paper will consider the various interactions that occur within the clothing system that contribute to wearer comfort. The dynamic interaction of the clothing material with large areas of the skin surface changes the perception of wetness felt by the user. To understand how sensation of wetness perception is influenced by textile parameters, a number of textile samples with different thickness, fiber type, and surface texture, were tested. They were evaluated in Static (upper back) and Dynamic (inner forearm) contact with the skin, under both low and high application pressure. Wetness perception and stickiness sensation (tactile cue) were measured with ordinal perception scales and local skin temperature (thermal cue) by thermocouples. Under Static contact, wetness perception in fabrics containing the same amount of moisture per volume was positively related to fabric thickness ($r^2 = 0.87$). Under Dynamic, higher wetness perception was associated with greater stickiness sensation ($r^2 = 0.68$), occurring from differences in fabric surface texture. Under Dynamic fabric thickness did not correlate with wetness perception directly, however when combined with stickiness sensation it provided a strong predictive power ($r^2 = 0.86$). In both Static and Dynamic conditions, greater wetness perception ($p < 0.05$) was observed in High compared with Low pressure condition; interestingly when matching for thickness, fiber type (cotton, polyester) did not affect wetness perception ($p > 0.05$). Fabric thickness and surface texture properties trigger thermal and tactile inputs, respectively, underpinning skin wetness perception in static and dynamic clothing applications. Additionally, fabric weight and clothing fit could cause changes in fabric-to-skin pressure, which represents another tactile sensory modality contributing to skin wetness perception. Consideration of these factors could aid the design of clothing and fabric products, particularly office and vehicle seating, towards optimising comfort.

Keywords: Clothing, Comfort, wetness perception.

1. Introduction

Comfort is often considered in relation to a single factor causing discomfort, be it environmental, physical, physiological or perceptual. But rarely does one factor actually fully influence how comfortable an individual feels. The clothing system can be considered to be a combination of components between which there are interactions which build to a final overall performance, from the basic fibre used to make the fabric to the end use of the product. Currently the understanding of the impact of individual textile and fabric parameters on wear perception is limited. This paper will consider the various interactions that occur within the clothing system that contribute to wearer comfort.

Within the clothing system numerous factors; fit, material, design, etc, can affect an individual's comfort perception. Clothing is not a passive cover for the skin, it interacts with the body changing the level of thermoregulation required accordingly. This interaction and effect varying with physical properties of the clothing (1). The properties of textile fabrics and garment embrace both mechanical and heat moisture/transfer properties, the complex effect of these properties characterise the comfort of the fabric consistency with reference format (2). This highlights the need for multiple factors to be considered during the evaluation of clothing.

Manufacturers can evaluate the physical properties of fabrics and materials through a number of test methods. These give a comparison between materials but do not link easily through into measures of wearer comfort. A particular factor influencing wearer comfort is skin wettedness, the sensation of moisture on the skins surface leading to discomfort (3,4). During activity, the production of sweat causes moisture build-up at the skin surface - clothing interface. This results in a perception of wetness leading to thermal and sensorial discomfort. In absence of skin hygro-receptors (5), wetness perception occurs through the central integration of thermal and tactile stimulations. The dynamic interaction of the clothing material with large areas of the skin surface changes the perception of wetness felt by the user.

This recent work aims to link the physical properties of fabrics to perception felt by the user both under static and dynamic conditions.

2. Method

To understand the textile parameters that contribute to the sensation of wetness perception, a number of textile samples with different thickness, fiber type, and surface texture, were tested. They were evaluated in Static (upper back) and Dynamic (inner forearm) contact with the skin, under both low and high application pressure. Wetness perception and stickiness sensation (tactile cue) were measured with ordinal perception scales and local skin temperature (thermal cue) by thermocouples.

Study 1- static interaction

Twenty-four knitted fabric samples (100 x 100 mm) selected for different structure, thickness and fibre type were evaluated.

Twelve 7 male / 5 female participants (23.4 yrs. ± 2.4), (Western European origin), participated in this study.

Fabrics were assessed in four separated trials which differed in the amount of water applied: 100REL – 100% absorption capacity (μL)/fabric volume (mm^3); 50REL - 50% absorption capacity (μL)/fabric volume (mm^3); ABS – same absolute water content 2400 μL, DRY – control. Fabrics were assessed by using a quantitative sensory test, which consisted of placing, 24 fabrics with different wetness levels on the upper back of each participant. Participants reported their local wetness perception, thermal sensation and thermal comfort on ordinal scales. The trials were completed in a counter balanced order and all experiments were performed in a climate controlled room, air temperature 25°C, relative humidity 50% and air velocity < 0.05 m/s.

In the experimental trials, participants entered the controlled climatic room and lied prone on a bench wearing underwear only. After a stabilization period in the room, each experimental fabric was applied on the participants' upper back for a period of 20 seconds. At the end of the 20 seconds stimulation period, participants were encouraged to verbally report their wetness perception, thermal sensation and thermal comfort for the stimulated area, using the three interval scales Fig 1. Additionally, since the continuous application of wet stimuli may decreases one's sensitivity, 1 min of rest, before the subsequent fabric application also allowed the recovery of the sensory system. The same protocol was repeated for each of the 24 fabrics.

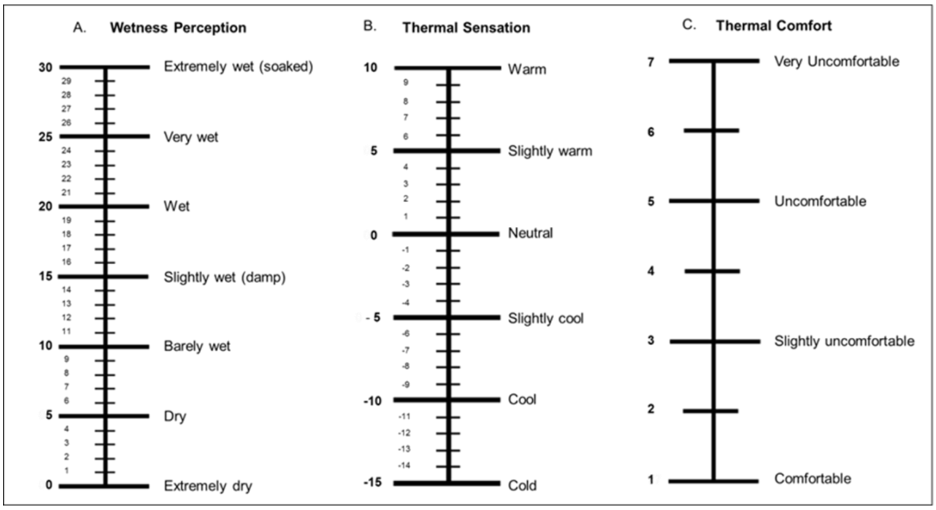

Fig. 1. Subjective scales – Study 1

Study 2 – dynamic interaction

Eight knitted fabrics (120 x 100 mm) selected for different structure, fibre type, surface texture properties, thickness, and treatments were included in this experiment.

Sixteen male (8) and female (8) (yrs. 22.4 ± 2.5), participants, of (Western European & North American origin), participated in this study. They were exposed to 8 fabrics under four experimental conditions DRY – control, WET - 50% absorption capacity (μL)/fabric volume (mm^3), WET LOW-P (Low pressure application - 127 Pa) and WET HI-P (High pressure application - 236 Pa).

Each fabric sample was placed in a custom made linear motion rig. The sample was connected to a motor drive on one side and to a counterweight on the other side. The fabric sample could run over two free running rollers, creating a horizontal area of stimulation. Under this area, the right forearm of each participant was placed such that the fabric touched the ventral forearm. The latter's setting was adjustable vertically to ensure equal pressure/ contact area in different size arms. The ventral forearm presents the same sensitivity to cold stimuli as the upper back (6), therefore the results can be compared with the static application (study 1). Participants were screened from the experimental textile samples before, during and after the application process, therefore any visual influence on the perceptual responses was prevented.

Each fabric sample was pulled bi-directionally across the skin at a velocity of 0.02 $m.s^{-1}$. Two fixed levels of pressure were applied, 127 Pa (LOW-P) and 236 Pa (HI-P) and the order of this two pressure conditions was counterbalanced. The the range of travel of each fabric was of 5 cm per stroke, with a total of 8 strokes per fabric. At the end of the exposure, participants were encouraged to verbally report their wetness perception, texture – roughness/smoothness, stickiness and pleasantness sensations for the stimulated area, using the four interval scales, Fig 2.

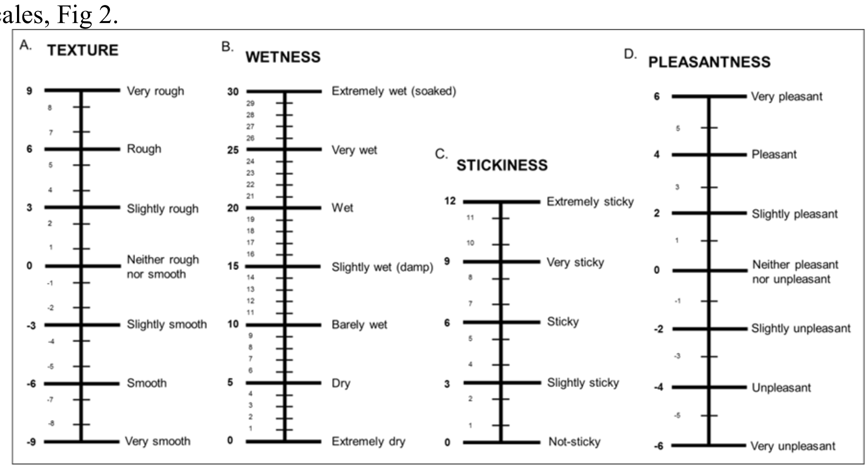

Fig. 2. Subjective scales – study 2

3. Results

The static study showed that wetness perception in fabrics containing the same amount of moisture per volume was positively related to fabric thickness ($r^2 = 0.87$), Fig 3.

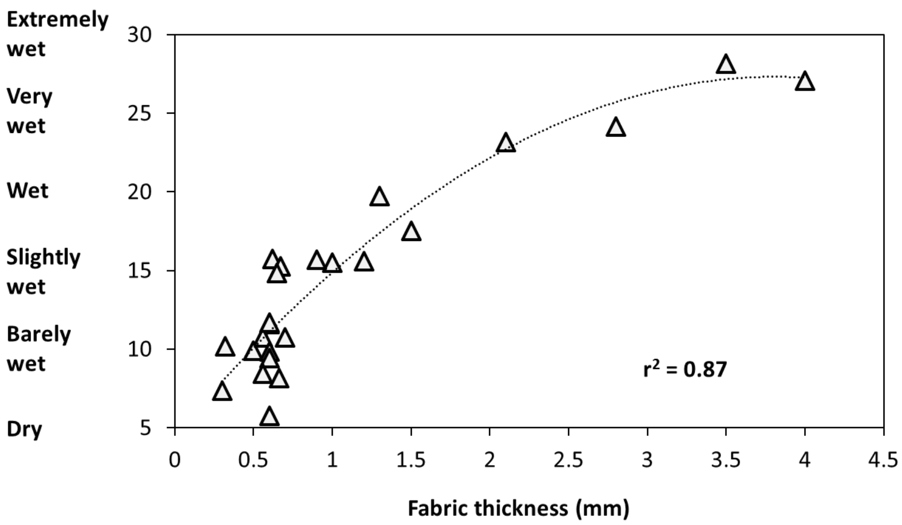

Fig. 3. Relationship between wetness perception and fabric thickness.

However, Under Dynamic conditions, higher wetness perception was associated with greater stickiness sensation ($r^2 = 0.68$), occurring from differences in fabric surface texture; additionally, fabric thickness did not correlate with wetness perception directly, however when combined with stickiness sensation it provided a strong predictive power ($r^2 = 0.86$) Fig 4.

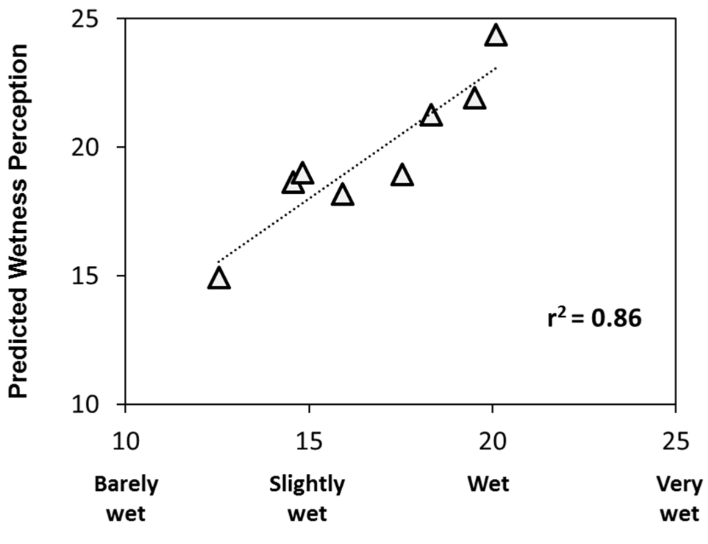

Fig. 4. Relationship between wetness perception and predicted wetness perception (stickiness + thickness)

In both Static and Dynamic conditions, greater wetness perception responses ($p < 0.05$) were observed in High pressure application compared with Low pressure application; interestingly when matching for thickness, fiber type (cotton, polyester) did not affect wetness perception ($p > 0.05$).

In the static condition, the strong impact of wetness perception on comfort was indicated by a linear positive relation between thermal comfort and wetness perception ($r^2 = 0.86$), Fig 5.

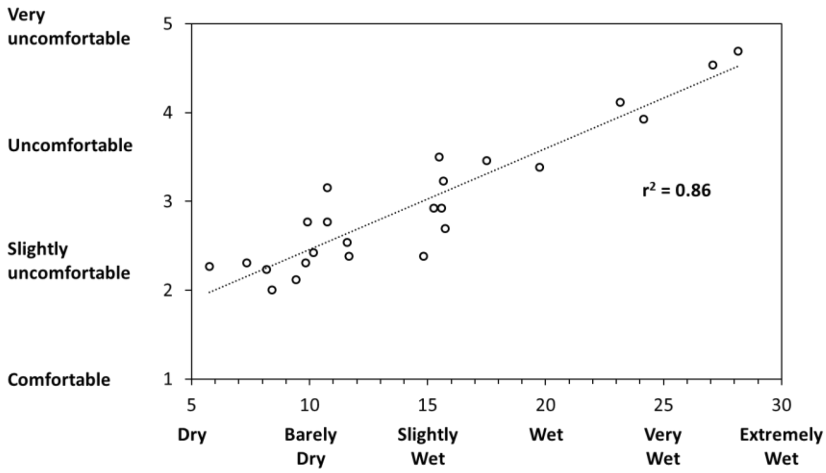

Fig. 5. Relationship between thermal comfort and wetness perception.

4. Conclusions

Fabric thickness and surface texture properties trigger thermal and tactile inputs, respectively, underpinning skin wetness perception in static and dynamic clothing applications. Which leads to perceptions of thermal comfort also being strongly driven by the moisture trapped in the wearers clothing Additionally, fabric weight and clothing fit could cause changes in fabric-to-skin pressure, which represents another tactile sensory modality contributing to skin wetness perception. It is important to note that single material factors, thickness, texture, etc, within the clothing system can have an interactive effect when combined into the finished product. This indicates that simple material testing and evaluation is not enough to ensure wearer comfort.

Consideration of multifactorial interactions could aid the design of clothing and fabric products, particularly between fabric systems, i.e., clothing and office or vehicle seating, towards optimising comfort.

5. References

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