A Multi-factorial Approach for the Assessment of Comfort in Clothing – A Footwear Application

A.M. WEST, G. HAVENITH and S. HODDER*

Environmental Ergonomics Research Centre, Loughborough Design School, Loughborough University, Loughborough, UK

* Corresponding author. Tel.: +44-150-922-3685. E-mail address: s.hodder@lboro.ac.uk

Abstract The perception of comfort is a complex and multi-factorial phenomenon based upon three main components: (i) psychological factors relating to an individual's role, values and social being, (ii) sensorial factors relating to the thermal, tactile and pressure sensations generated between clothing and the skin and (iii) physiological factors which affect body function during activity i.e. mechanical aspects (fit, level of support) and thermal aspects (heat and moisture transfer) (1,2). The evaluation of comfort in clothing has primarily been determined in relation to the physiological component. The exploration and understanding of psychological and sensorial factors of comfort is therefore limited. This paper will consider the methods which can be used to explore all three components of comfort and the insights gained from undertaking a multi-factorial approach. This multi-factorial approach was adopted in relation to a footwear application investigating the importance and role of the sock on comfort within the foot-shoe system. Four socks identical in design/construction but different in fibre composition (94% of either cotton, wool, polyester or coolmax with 3% polyamide and 3% elastane) were used for the assessment. Psychological factors were explored using Best-Worst Scaling to allow for the assessment of attribute importance and consumer preferences. Sensorial factors of comfort for each sock were evaluated by filling in a questionnaire containing 15 sets of opposing adjectives (e.g. thick vs thin, comfortable vs uncomfortable) to allow for semantic profiling. This was performed at rest with socks being applied to the participants feet (passive assessment) and following exercise (dynamic assessment). The evaluation of physiological comfort was achieved through completion of five running trials performed on separate occasions for each sock and without a sock. Foot skin temperature, in-shoe temperature and in-shoe humidity were monitored throughout. Subjective ratings (thermal sensation, wetness perception, stickiness and thermal comfort) for the foot were recorded. Comfort and functionality were identified as important attributes influencing sock purchase. Assessments performed passively allowed for sensitive discrimination of textile properties between sock conditions (i.e. rough/smooth, scratchy/silky). During dynamic assessment however, the ability to discriminate between textile properties reduced. Wearing socks during running reduced discomfort compared to not wearing a sock but did not affect shoe microclimate. Overall, assessment of clothing comfort utilising a multi-factorial approach indicated that: (1) assessment of sock properties change from passive to dynamic assessments, (2) socks influence sensorial comfort within the foot-shoe system but have little physiological impact and (3) running without socks result in greater thermal discomfort compared to running with socks.

Keywords: Comfort, Multi-factorial interactions, Footwear

1 Introduction

The perception of comfort is a complex and multi-factorial phenomenon based upon three main components: (i) psychological factors relating to an individual's role, values and social being, (ii) sensorial factors, relating to the thermal, tactile and pressure sensations generated between clothing and the skin and (iii) physiological factors which affect body function during activity i.e. mechanical aspects (fit, level of support) and thermal aspects (heat and moisture transfer) (1,2).

The evaluation of clothing comfort has primarily been determined in relation to physiological factors. Havenith (3) showed how parameters relevant to heat exchange processes (air and radiant temperature, humidity, wind speed, metabolic production and clothing insulation) impact a worker's thermal stress and highlighted the relevance of clothing design, clothing fit and clothing air permeability. Knowledge of human local sweat patterns (4) have recently been applied to the design of sportswear. Results have shown improvements in thermo-physiological responses and thermal perception for body mapped ensembles compared to traditional ensembles when running in a warm environment (5).

Sensorial factors have also been evaluated, primarily through touch and interaction with textiles, the process of which is referred to as the 'fabric hand'. Although there is lack of consensus regarding the psychophysical techniques to apply, the use of semantic profiling (bipolar rating scale consisting of opposite word pairs i.e. hot – cold, rough – smooth) is now frequently used (6–8). Semantic profiling allows for the identification of specific sensory qualities (hot – cold, rough – smooth etc.) but also the perceived magnitude of those sensations (very hot, slightly rough etc.). Primarily assessed through the 'fabric hand', it is not known how these sensations translate to the sensations experienced when a garment is worn at rest or during activity. Moreover, there are no subjective criteria relating to hand feel (9) and so the specific qualities and magnitude of sensations required for clothing comfort have not been identified.

Despite growing interest, the exploration and understanding of psychological factors of comfort is limited. To identify consumer needs and expectations, researchers have assessed the importance given by consumers to various clothing attributes such as fit, price and comfort etc. (10,11). However, discrimination between attribute importance is not always possible when using rating scales as respondents often rate all attributes as 'important'. Best-Worst scaling commonly used in sensory science to explore consumer perceptions to food products and packaging allows for greater discrimination of attribute importance. Individuals are required to identify the best and worst attributes for combinations of profiles relating to clothing features and characteristics (12,13). Although the method has not been applied within clothing science, identification of consumer expectations is useful for product innovation and marketing.

This paper will consider the methods which can be used to explore all three components of comfort in clothing and the insights gained from undertaking a multi-factorial approach. This multi-factorial approach was adopted in relation to a footwear application investigating the importance and role of the sock on comfort within the foot-shoe system.

2 Method

10 healthy females [age: 23 ± 4 years; height: 169.1 ± 4.6 cm; body mass: 62.7 ± 8.2 kg; foot size: 6.5 ± 0.6 UK] volunteered to participate in this study. Participants were required to visit the laboratory for 6 experimental sessions performed in a climatic chamber maintained at 23°C, 50% RH.

Four socks identical in design/construction (ankle length, single jersey, ribbed cuff) but different in fibre composition (94% of either cotton, wool, polyester or coolmax with 3% polyamide and 3% elastane) were used for the assessment of comfort. Socks were matched for thickness and mass.

During the first experimental session, the assessment of psychological comfort was performed using Best-Worst scaling. 13 key attributes (Table 1) were identified from clothing literature (6,9). Using a balanced, incomplete block design, 13 choice sets were formed with each set containing four attributes (Table 2). Each attribute appeared once with each other and appeared four times across choice sets. All 13 choice sets were presented to respondents in a questionnaire (Fig.1).

Table 1. Attributes consumers considered when purchasing socks for use during running

Attribute no.	*Attribute*
1	Price
2	Colour
3	Fit
4	Length
5	Thickness
6	Material (cotton, wool, polyester)
7	Material weave (plain, knitted, ribbed)
8	Attractiveness
9	Brand name
10	Durability
11	Ease of care
12	Functionality (moisture management, breathability, anti-blister)
13	Comfort

Table 2. Balanced incomplete block design for the assessment of 13 attributes utilising a Best-Worst scaling approach

Choice set	*Attribute number*			
1	1	2	4	10
2	2	3	5	11
3	3	4	6	12
4	4	5	7	13
5	5	6	8	1
6	6	7	9	2
7	7	8	10	3
8	8	9	11	4
9	9	10	12	5
10	10	11	13	6
11	11	12	1	7
12	12	13	2	8
13	13	1	3	9

Considering only these four attributes, which one would be most important and least important when purchasing socks for use during running?

Most important	**Attribute**	**Least important**
☐	Price	☐
☐	Colour	☐
☐	Length	☐
☐	Durability	☐

Fig. 1. An example choice set presented to respondents utilising a Best-Worst scaling approach for the assessment of attributes considered when purchasing socks for use during running.

For the assessment of sensorial comfort, participants were required to evaluate each sock during a passive assessment using a questionnaire. Socks were applied onto the feet and removed by the experimenter with each sock type assessed in turn. Participants were shielded from seeing the socks, performing the evaluations seated behind a black drape. The questionnaire contained 15 sets of opposing adjectives (e.g. thick vs thin, comfortable vs uncomfortable) each arranged on a five-point bipolar scale to allow for semantic profiling.

Experimental sessions 2-6 involved running in each of the experimental socks on separate occasions (dynamic assessment). One trial was performed without a sock. Participants were not allowed to visually inspect the socks and they were not provided with information regarding sock related differences. Participants donned test shoes and rested for 10 minutes before performing 40 minutes of running at a constant speed (7.5 $km.hr^{-1}$). This was followed by a 15 minute recovery period.

Foot skin temperature (t-type thermocouples) and in-shoe temperature and in-shoe relative humidity (SHT31, Sensirion, Switzerland) was measured at seven sites on the right foot. In-shoe measurements were made by applying sensors to each sock/to the skin for the no sock trial using transpore surgical tape. Data was collected with a specially developed Bluetooth data acquisition system (University of Applied Sciences Kaiserslautern, Zweibrücken, Germany), secured to the participants ankle (14). Ordinal scales were used to assess thermal sensation, wetness perception, stickiness and thermal comfort for the right foot every 5 minutes.

Following each trial, participants were required to evaluate the socks worn by filling in the questionnaire used in the first experimental session for sematic profiling. This allowed for a dynamic assessment of sensorial factors of comfort following exercise.

2.1 Analysis

Best-Worst Scaling: An overall sum of best (B) and worst (W) votes for each attribute was determined by totaling the number of times each attribute was selected as most important and least important. To determine a B-W score for each attribute, the number of times it was least important was subtracted from the number of times it was most important. The average B-W score was calculated (Equation 1) by dividing the totals of B-W scores by the number of responses and the frequency that each attribute appeared in the design of choice sets.

$$Average\ Best - Worst\ score = \frac{Best\ scores - Worst\ scores}{(number\ of\ respondents\ \times attributes\ per\ set)} \qquad (1)$$

Semantic profiling: An average score based upon the five-point scale for each set of opposing adjectives was taken forward for graphical representation. To assess differences between sock properties for passive and dynamic assessments a Friedman test was conducted. When significant effects were observed, post hoc analysis was conducted with a Wilcoxon signed rank test.

Physiological responses: The mean foot response for each individual variable (foot skin temperature, in-shoe temperature and in-shoe relative humidity) was calculated by averaging the data recorded from seven foot measurement sites for each participant over time and taken forward for statistical analysis. To investigate whether shoe microclimate was affected by sock fibre type and time a two-way repeated measure analysis of variance (ANOVA) was performed with post hoc multiple comparisons (Bonferroni correction). To investigate subjective perception of shoe microclimate between sock conditions a Friedman test was conducted. When significant effects were observed, post hoc analysis was conducted with a Wilcoxon signed rank test.

3 Results

The most important attributes to consumers when purchasing socks were comfort and functionality (Fig.2).

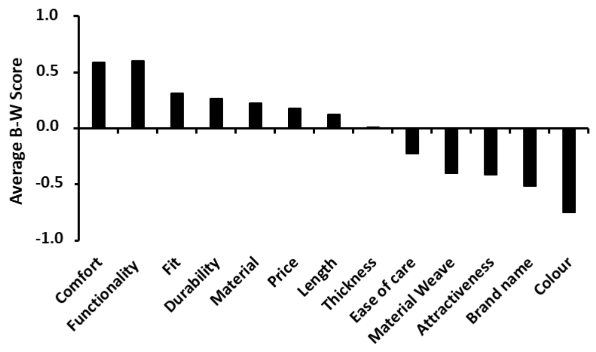

Fig. 2. Average Best-Worst scores for 13 sock attributes

Foot feel assessments performed passively (Fig.3a), showed that the cotton sock was identified as rougher and scratchier compared to the other socks ($p < 0.05$). Participants only identified a difference in fibre composition (natural vs synthetic) between the wool and polyester sock ($p=0.01$). The wool sock was perceived as being less restrictive compared to cotton ($p=0.02$) and coolmax ($p=0.03$) socks. The cotton sock was identified as less comfortable, less pleasant, less satisfactory and less acceptable in comparison to wool, polyester and coolmax socks ($p < 0.05$).

Foot feel assessments performed dynamically after exercise (Fig.3b) indicated no differences in texture related sock properties (rough/smooth, scratchy/silky). Participants identified the wool sock as being natural in composition compared to the cotton ($p=0.02$), polyester ($p=0.05$) and coolmax ($p=0.01$) socks which were perceived as being more synthetic. No differences in toe restriction were identified. All socks were comfortable, pleasant and satisfactory. The wool sock was rated less acceptable for wear during running compared to synthetic socks ($p < 0.05$). For both passive and dynamic assessments, there were no differences in thermal perception based upon sock fibre composition.

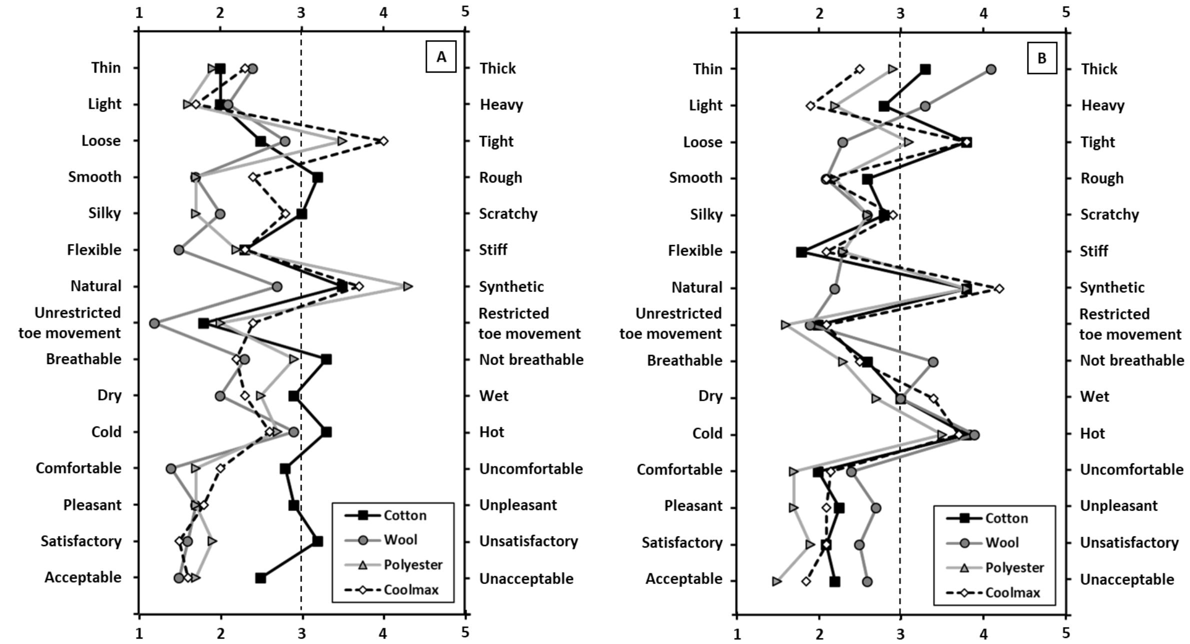

Fig. 3. Semantic profiles for the assessment of four socks (cotton, wool, polyester and coolmax) during (a) passive foot feel assessment and (b) dynamic foot feel assessment following exercise

Assessment of thermal aspects relating to physiological factors of comfort revealed that during exercise there was no main effect of condition or condition*time on mean foot skin temperature, mean in-shoe temperature or mean in-shoe relative humidity.

No differences in thermal sensation, wetness perception or stickiness were observed between sock conditions. Wetness perception and stickiness were higher for the no sock condition during run ($p < 0.05$) which resulted in greater thermal discomfort ($p < 0.05$) in comparison to the sock conditions.

4 Conclusions

The identification of comfort and functionality as attributes which are important to the consumer when purchasing socks for running provide important insights to the process of product design but also for effective marketing, as packaging/labelling can communicate functional and information benefits to the consumer.

Foot feel assessments performed passively allowed for sensitive discrimination of textile properties between sock conditions (i.e. smooth/rough, scratchy/silky). During dynamic assessment however, the ability to discriminate between textile properties reduced. Greater sensitivity during passive assessments were important, driving the perception of (dis)comfort. Cotton socks were perceived as rougher and scratchier and consequently more uncomfortable, unpleasant, unsatisfactory and more unacceptable in comparison to the wool, polyester and coolmax socks.

Running without a sock results in greater thermal discomfort. The type of sock worn however, has no discernible effect on an individual's thermal comfort. Running in socks of different fibre compositions or running without a sock did not affect foot skin temperature or shoe microclimate (in-shoe temperature and in-shoe relative humidity) in the conditions used.

Overall, assessment of clothing comfort utilising a multi-factorial approach indicated that: (1) assessment of sock properties change from passive to dynamic assessments, (2) socks influence sensorial comfort within the foot-shoe system but have little physiological impact and (3) running without socks has little physiological impact but results in greater thermal discomfort compared to running with socks.

5 Referencing

1. Pontrelli G. Partial analysis of comfort's gestalt. In: Clothing comfort:interaction of thermal, ventilation, construction and assessment factors. 1977. p. 71–80.
2. Sontag S. Clothing and Textiles Research Comfort Dimensions of Actual and Ideal Insulative Clothing for Older Women. Cloth Text Res J. 1985;4(1):9–17.
3. Havenith G. Heat balance when wearing protective clothing. Ann Occup Hyg. 1999;43(5):289–96.
4. Smith CJ, Havenith G. Body mapping of sweating patterns in male athletes in mild exercise-induced hyperthermia. Eur J Appl Physiol [Internet]. 2011;111(7):1391–404. Available from: http://link.springer.com/10.1007/s00421-010-1744-8
5. Wang F, Cai X, Zhang C, Shi W, Lu Y, Song G. Assessing the performance of a conceptual tight-fitting body mapping sportswear (BMS) kit in a warm dry environment. Fibers Polym. 2016;17(1):151–9.
6. Cardello A V, Winterhalter C, Schutz HG. Predicting Military Sensory Development Application Psychophysical. Text Res J. 2003;73(3):221–37.
7. Alcántara E, Artacho MA, González JC, García AC. Application of product semantics to footwear design. Part II - Comparison of two clog designs using individual and compared semantic profiles. Int J Ind Ergon. 2005;35(8):727–35.
8. Alcántara E, Artacho MA, González JC, García AC. Application of product semantics to footwear design. Part I - Identification of footwear semantic space applying diferential semantics. Int J Ind Ergon. 2005;35(8):713–25.
9. Bishop DP. Fabrics: Sensory and Mechanical Properties. Text Prog. 1996;26(3):1–62.
10. Fowler D. The Attributes Sought in Sports Apparel: A Ranking. J Mark Theory Pract. 1999;7(4):81–8.
11. Swinker ME, Hines JD. Understanding consumers' perception of clothing quality: A multidimensional approach. Int J Consum Stud. 2006;30(2):218–23.
12. Finn A, Louviere JJ. Determining the Appropriate Response to Evidence of Public Concern: The Case of Food Safety. J Public Policy Mark. 1992;11(2):12–25.
13. Louviere J, Lings I, Islam T, Gudergan S, Flynn T. An introduction to the application of (case 1) best-worst scaling in marketing research. Int J Res Mark [Internet]. Elsevier B.V.; 2013;30(3):292–303. Available from: http://dx.doi.org/10.1016/j.ijresmar.2012.10.002
14. West AM, Schönfisch D, Picard A, Tarrier J, Hodder S, Havenith G. Shoe microclimate: An objective characterisation and subjective evaluation. Appl Ergon [Internet]. Elsevier; 2019;78(July 2018):1–12. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0003687019300171