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Psychometric properties of the hand of polyester/cotton blend fabrics

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PSYCHOMETRIC PROPERTIES OF THE HAND OF POLYESTER/COTTON BLEND FABRICS

by

Mary Ellen Wiczynski

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APPROVAL PAGE

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The psychometric properties of rating scale, rank order and paired comparison methods of fabric hand evaluation were determined. The Kawabata Evaluation System (KES) was used to measure fabric properties that have been used to objectively characterize fabric hand. The relationship between subjective and objective measurements was discussed.

Responses to a terminology survey guided the specification of hand attributes that influence the selection of polyester/cotton bottom weight fabrics. Eleven expert judges evaluated the flexibility, surface roughness, weight, thickness and end use suitability of 27 polyester/cotton bottom-weight fabrics randomly assigned to three groups. Fabrics judged most suitable for use in men's summer dress slacks were most pliable, most smooth, thinnest and lightest in weight.

Analyses of multitrait-multimethod correlation matrices showed that there was no difference between the methods in terms of validity or reliability. The subjective measurements of flexibility, weight and end use suitability were valid. For the evaluation of flexibility, surface roughness, weight and thickness, the rank order evaluation method required the fewest number of judges to achieve a reliability of .90. The level of correlations differed between the three fabric groups.

The correlation between KES measurements of fabric properties and the subjective measurements of fabric hand differed between the three fabric groups. Regression equations developed from the subjective and

objective measurements of fabric hand properties of a sample of nine polyester/cotton bottom-weight fabrics did not predict the hand attributes of another sample of the same size from the same population.

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1. INTRODUCTION

The physical properties of a fabric influence how it performs when it is handled and manipulated, how easily it can be transformed from a two-dimensional shape to cover the three-dimensional form of the human body, and how it moves when the body it covers moves. These properties are measured and evaluated as force is applied and the fabric is deformed. Measurable deformations include bending, compression, elongation and shearing.

These same parameters cause sensations that affect nerves and muscle endings when a fabric comes in contact with the skin (35). Therefore, as well as being measured objectively through mechanical instrumentation, these properties can also be measured subjectively through the human sense of touch. The term "hand" has been applied to this subjective property because fabric has traditionally been judged by the fingers of the hand.

Recognizing one specific definition of "hand" is difficult because many have been given. Vaughn and Kim (62) reviewed the literature and identified eleven different definitions of the term. They noted that the terminology used usually depended on the frame of reference of the individual investigator. Although there is no one formal definition for the concept of fabric hand all do refer, either directly or indirectly, to the subjective measurement of sensations produced by fabric as perceived through the skin--specifically the skin of the hand.

Definitions cited include "a properly judged function of the feel of the material which is composed of sensations of stiffness/limpness, hardness/softness, roughness/softness" and also "the impressions which arise when fabrics are touched, squeezed, rubbed or otherwise handled." Fabric hand has also been described as "an estimation of a fabric's feel when using the fingers and thumb--one of the most rapid assessments that can be made of the quality of a fabric." Lastly, hand has been considered to be "the summation of the weighted contributions of stimuli evoked by a fabric on the major sensory centers."

There is a variety of test methods which measure the physical and mechanical properties that constitute the hand of fabrics. Sensitive instruments have also been developed which match the degree of deformation to that applied when a fabric is manipulated by the hand (28).

A major goal is to use these objective methods to predict or specify the hand of fabrics. There are now fewer "experts" in textile and apparel industries who can accurately evaluate the hand of fabrics. It is time consuming and expensive to train and maintain evaluation panels within an organization. This work is also justified by increased mechanization in all areas of the textile and apparel industry. One aim is to translate the subjective concepts of hand into terminology machines can understand. For these reasons, much work has been done in correlating objective and subjective evaluations of fabric hand.

The methods of subjectively measuring the hand of fabrics have involved the assignment of numbers to concepts traditionally considered qualitative. There are numerous methods, the choice of which depend on investigator knowledge, types of judges, types and number of stimuli. Researchers are often confused as to which method is appropriate for their work. There is a need for a systematic approach to establishing the reliability, validity and efficiency of subjective hand evaluation methods.

The goal of this research is to establish the reliability, validity and efficiency of selected subjective hand evaluation methods in order that the correlation of objective and subjective hand evaluation can be more precisely standardized. The experimental design of this project is based on a review of the literature in the following areas: 1) methods of subjective measurement, 2) terminology, 3) sensory evaluation panels, 4) fabrics, 5) methods of objective measurement, and 6) correlation of objective and subjective measurements of fabric hand.

2. REVIEW OF LITERATURE

2.1. Methods of Scaling Stimuli Attributes.

Sensory evaluation involves the measurement of a person's perception of a stimulus. The measurement process consists of assigning to an object a number which indicates the quantity of an attribute the stimulus is perceived to possess. The methods or protocols which describe the procedures for assigning numbers are called scaling models or measurement methods (47). A data matrix is constructed between stimuli, judges, and their responses to stimuli. The matrix is manipulated or collapsed across stimuli when the research interest is in differences between judges. When the interest is in the differences between stimuli such as types of fabrics, the matrix is collapsed across judges, which are considered replications of the experiment.

The methods of measuring subjective response have three common elements (17):

a. A pattern for presenting items to subjects

b. Questions to pose to the subject and a form which the answers must take on

c. A method of analysis

There are many different scaling methods described in the literature. There are also variations of methods which have been developed either as psychometric theory has evolved or as various areas of research turned to psychometrics for new dimensions in their experimental design. It is often found that scaling methods with different names are in fact the same. Efforts to clarify and analyze scaling methods have resulted in a number of classification systems.

Criteria for classification can be based on ways in which scaling methods differ (59). Some of the different aspects include:

1) Properties of the final scale: nominal, ordinal, interval, ratio.

2) Availability of a related physical continuum: psychophysical methods have a physical continuum available; psychological methods do not.

3) Nature of response: depends on whether the relationship of interest is between response and stimuli or response and subject; the response may be comparative or categorical.

4) Field of specialization: procedures differ according to the field in which the research is being conducted; types include attitude scaling and aesthetic preference methods.

5) Experimental procedures: various types include rating methods, sorting methods, method of paired comparisons.

The following discussion of scaling methods will be classified according to the type of experimental procedure used in the method. In the field of hand evaluation, one concern is with the selection of the best and most efficient scaling method. When viewed from this perspective, it will be possible to describe the procedures, present advantages and disadvantages and discuss applicable statistical or variable re-expression procedures when necessary or appropriate.

2.1.1. Magnitude Estimation Method.

Doehlert (17), Larmond (36), Moskowitz (44), Stevens (60) and Wells (60) have discussed this evaluation method. In this procedure the subject is presented one item at a time and is asked to assign a number to the stimulus that corresponds to his subjective response. The number assigned to the first object is arbitrary and can be specified by the subject or the experimenter. The remaining items in the set are assigned numbers based on the first value assigned. The values assigned are referred to as magnitude estimates.

The values obtained can be used in the response form. When the judgments of many subjects is to be combined the data is normalized. Doehlert (17) describes one method by which the data from each person is normalized by dividing each data point by the number for the first item presented in each set giving each a base point of 1.0.

Moskowitz (44) asked judges to assign scale values to a Likert-type scale that corresponded to the scale they had used in evaluating the stimuli. A "pivot" was obtained by averaging the scale values excepting "0". A new magnitude estimation value was obtained by dividing the old value by the pivot and multiplying by 100.

An advantage of using a magnitude estimation method is that it can be a relatively fast method. It has a number of disadvantages however. Because a judge has to remember previous judgments, estimates may shift during a series of evaluations. It is also believed that judges do not handle the real number line well and that the difference of one point of magnitude located at 10 is perceived differently from one located at 85 on the number line.

Sources differ in their conceptions concerning the final scale of the data obtained by this method. As the method is described above the data is considered to be scaled in equal intervals. A second source (5) proposes that the scale depends on how the method is explained to the judges. If the judge is directed to think of responses in terms of ratios, then the final scale values can be considered ratio scale.

2.1.2. Ratio Estimation Method.

This method is believed to be a solution to the disadvantages of the magnitude estimation procedure and is discussed by Doehlert (17) and Larmond (36). A judge is presented two items and is asked to estimate the ratio of their difference. One specified item may be common to every pair. The common item is assigned an arbitrary number. The data is normalized by multiplying the value of the ratio of each assigned value to the common value by the assigned value.

There are advantages to this method in comparison to magnitude estimation. It is as fast or faster because ratios are considered easier to estimate (17). Scale shifting does not occur. The method has disadvantages because judges can still be influenced by previous items evaluated in the set. Another disadvantage involves the incorporation of individual attitudes toward numbers and ratios into the data.

No examples have been found in the literature which used magnitude or ratio estimation methods in the evaluation of fabric hand attributes.

2.1.3. Rating Methods.

This type of scaling method has been discussed in the literature related to sensory evaluation by Larmond (36), Moskowitz (45), Wells (63) and in the ASTM Manual on Sensory Testing Methods (5). The procedure asks a judge to evaluate a stimulus by using a scale containing equally spaced degrees of magnitude. The purpose of the rating scale is "to create the impression of a continuum related to some unidimensional concept and provide the subject a ready means of locating an object in relative position on that continuum (5)." The subject uses the scale to estimate the magnitude of his reaction to the stimulus. The final scale of the data obtained from this method is interval.

The types of rating scales used have been described as follows (5):

i) Graphic scales: either a simple line or one marked off into segments. Direction, that is, which end is "good" and which end is "bad" or which is "more" or which is "less", must be shown.

ii) A verbal scale: consisting of a series of brief written statements, usually the name of the dimension with appropriate adverb or adjective modifiers, which are written out in appropriate order.

iii) Numerical scales: consisting of a series of numbers ranging from low-to-high, which are understood to represent successive levels of quality or degrees of a characteristic.

iv) Scale of standards: where the distinguishing feature is the use of actual physical samples of material to represent the scale categories. Sometimes such scales are partial, that is some but not all of the scale categories are represented by physical standards.

Number of intervals varies. In hand evaluation studies researchers have used yes-no (1-0) scales and scales with four, five and six steps. A semantic differential scale uses a 7-point scale (49). It is important to note that even-point scales have no midpoint, and therefore the judge is forced to make a choice with no opportunity for neutrality.

Winakor, et al. used a 99-point certainty scale in the belief that an advantage lies in the fine gradations and the large amount of information it provides (65). However it has been determined that the reliability gained from using more that seven intervals does not justify the extra effort (19). Beyond seven or nine intervals the model is fitting only additional error.

Advantages of this method are that the method is fast, numbers obtained can be used as they are obtained without re-expression, and the shifting of estimates is controlled by the points being fixed on the scale. Disadvantages lie in the fact that the assignment of numerical values to the scale is arbitrary and may not have a specific relation to the real scale of the stimulus. Also, the scale numbers may not have the same meaning for all judges.

Other names reported in the literature for rating methods are scoring, sorting into successive intervals, and direct scaling of magnitude.

Among those who have used this method to evaluate the hand of fabrics are Bogaty, et al.(10), David et al.(16), Lundgren (39), Matsuo et al.(43) and Paek (52).

2.1.4. Ranking Methods.

Sensory evaluation by ranking methods has been discussed in the literature by Larmond (36), Nunnally (47), and in an article by the Midwest Section of the American Association of Textile Chemists and Colorists (3). According to the procedure, the judge is presented with three or more items and is asked to rank order the items according to the degree to which they are perceived to possess the specified attribute.

The final data can be used as it is obtained and is considered to be ordinal. If the rank values are re-expressed as interval data (38) analysis of variance, t-test and multiple comparison techniques can be used.

Advantages of this method are that it is fast, several items can be evaluated at one time, and no memory of previous samples or judgments is required. One disadvantage of the method is that since stimuli are evaluated relative to the others in the set, the results from different sets cannot be compared with another set containing different samples. Another drawback is that no size of differences between items is obtained.

Ranking methods have been used to evaluate hand attributes of fabrics by Kawabata (29) and Barker and Scheininger (8).

2.1.5. Paired Comparison Method.

Paired comparison scaling methods have been discussed by David (15), Doehlert (17), Larmond (36), Wells (63), and in the ASTM Manual on Sensory Testing Methods (5). According to the procedure, a judge is presented with two items and asked to indicate preference based on the attribute specified. Values of "1" or "0" are assigned to choice and non-choice respectively. The data is summarized in a preference matrix. The final result is a complete ranking of all the items in the set.

The final data scale depends upon the method used to convert the data to numerical scale values. Methods cited include Bradley-Terry, Thurstone scaling, rankits, row sums, and powering (17). The method of data analysis used will depend upon the method used to convert the data to scale values.

Advantages of this method are that the judge is not required to compare more than two items at one time or to refer to standard items, and no memory of previous items is required. There are disadvantages to the use of this method however. The procedure becomes more complicated because as the number of items in the data set increases so does the number of pairs [for t items there are t(t-1)/2 pairs]. Analysis of data is more complex because comparisons do not produce scale values in usable form. Also, as with other ranking methods, an absolute amount of difference between stimuli is not determined.

In the evaluation of fabric hand attributes, the paired comparison method has been used by Harada, et al.(21), Howorth (26), Ripin and Lazarfeld (55), Nishimatsu (46), and Paek (52).

2.1.6. Scheffe' Paired Comparison Method.

In the literature, this scaling method has been discussed by David (15), Doehlert (17), Larmond (36), and Scheffe' (58). The procedure is carried out by presenting to judge with two or items and requesting that he or she indicate preference and size of difference based on the attribute specified. The judge is given a 7- or 9-point rating scale. The difference between items i and j is rated as follows:

+3 if i is greater and the difference is strong
+2 if i is greater and the difference is moderate
+1 if i is greater and the difference is slight
0 if there is no difference
-1 if j is greater and the difference is slight
-2 if j is greater and the difference is moderate
-3 if j is greater and the difference is strong

The scale value for an item is obtained by averaging the values for the item from each pair in which it was compared. If the item was the lesser the score would be -3 -2 -1, if the subject judged no difference the score would be 0, and if the item were judged greater its score would be +3 +2 or +1. Appropriate data analysis techniques include analysis of variance and multiple comparison methods.

An advantage of this method is that it gives initially more information than traditional paired comparison methods. Also, a judge has to compare only two items at one time and not compare with standards or recall previous judgments.

Disadvantages are that determination of difference is more difficult for judges and the same information is available from Thurstone scaling of standard paired comparison data. The assignment of scale values is arbitrary and their relationship to attributes is often not strongly established. Different judges interpretation of scale values may not be the same.

This method has also been referred to as rating of differences (17). No reference to the use of this method in the scaling of fabric hand attributes has been found in the literature.

2.1.7. Ranking of Three or More Items at a Time.

Doehlert (17) described this method as a variation of the paired comparison method in which a subject is asked to rank a set of items in groups of three or more. The rankings are reduced to paired comparisons and the data is analyzed accordingly. The number of items in a group depends on the type of attribute being evaluated, however the number usually ranges from three to ten.

When the number of items in the set gets large this method reduces the amount of time and effort required, which is an advantage as is the fact that it is not necessary to evaluate all possible combinations of triplets or quadruplets, etc. in order to evaluate all possible pairs in the item set.

The disadvantages associated with this method are the same as those given for the paired comparison method. The methods of data analysis are also the same. This method is also referred to as a triplet comparison method and has been used to evaluate the hand of fabrics by Olson (48) and Wiczynski et al. (64).

2.1.8. Forced Choice, Threshold, and Qualitative Analysis Methods.

These scaling methods have been discussed in relation to sensory evaluation (5) and have specialized uses. For this reason they will be discussed here briefly. Further information on them can be found in the literature.

Forced choice methods such as the triangle test, the duo-trio test, and the dual-standard test are used to discriminate between stimuli in regard to a specified attribute. These methods are sensitive to small differences. A judge is forced to choose one item from a number of items and the choice is designated to be correct or incorrect. A difference is detected when the number of correct choices is above the 50% probability level. The degree of difference is indicated by the proportion of correct choices.

Threshold methods are used to determine the minimum detectable level of a stimulus or minimum detectable difference in a stimulus. The establishment of thresholds is time consuming and is used in very specific stages of sensory evaluation. Matsuo et al. (43) worked in this area and determined detectable percentage differences for a number of basic fabric mechanical properties.

Qualitative analytical methods are used to identify the attributes of an item or product that should be evaluated for suitability or preference. They are procedures that are used with new products or in the early stages of comparative evaluation of items. The method involves soliciting information from a panel of judges concerning the properties of an item that are considered to be components of the quality of a product. This corresponds to methods used by Ripin and Lazarfeld (55) and Howorth and Oliver (26).

2.1.9. Standardization of Test Methods.

Many of the methods discussed in this section have been used extensively in areas of sensory evaluation such as aroma, taste, and color of foods. Much work has been done by Committee E-18 on Sensory Evaluation of the American Society for Testing and Materials. Many of the people serving on that committee are from the food, textile, and cosmetics industries. A task group formed within this committee is currently developing a standard method for the evaluation of fabric "handfeel".

Committee RA 89 on Hand Evaluation of the American Association of Textile Chemists is working along the same lines in developing a standardized procedure for the evaluation of the hand of fabrics. Neither of the procedures is available for publication outside of the respective committees. However neither committee is specifying scaling protocols or analysis of data in any detail.

2.2. Terminology of Hand.

The selection of words that describe the hand of fabrics is in itself a subjective process dependent upon who the judges are and the fabrics or processes being evaluated. This is evident in the literature in which many research papers include a list of terms that have been used to describe fabric hand characteristics. Bogaty, et al (10) evaluated the "harshness" of fabrics. The scale for this characteristic ranged from harsh to soft. Harshness was understood to contain the component of "prickliness caused by contact of the surface fiber ends with the fingers." It also included components of stiffness and compactness.

Other words found in the literature included "boring", "hungry", "weighty", "well-bedded", "rawky", "smooth", "hard", and "stiff". A list of hand terms is given in Appendix A.

The difficulty of identifying terms that have broad acceptance and understanding is compounded when attempts to communicate about this topic are international. The word "kindness" is often used as a descriptor of fabric hand. In the United States its meaning relates to the overall suitability of a fabric for a proposed end use (54). However it is used in England and Japan as a synonym for "softness"—the opposite of "harshness"(10).

It is also recognized that there is a difference in the understanding of fabric hand descriptors between expert and untrained judges of hand (65). Those who work in textile and apparel related fields will have a more highly developed sensitivity to fabric characteristics as well as a jargon of their own.

The basic function of language is supposed to be the "communication of meaning--the expression of ideas (49)." Usually, in order to find out what someone means when they speak, they are asked to explain themselves. Recognizing that a common understanding of terminology between judge and experimenter is key to the validity and reliability of hand evaluation. Hollies (24) believes that the most meaningful results are obtained when raters are allowed to use their own words when describing or evaluating a stimulus and he elicits terminology from judges before he develops the measurements scales he uses.

This philosophy is supported by Osgood, et al., in The Measurement of Meaning (49) in which they recommend that language used to represent or describe a concept should be elicited from judges in order that the terms can subsequently standardized across judges. In this way differences in interpretation can be eliminated as a variable.

These principles have been utilized by several researchers. Using the method of paired comparisons, Ripin and Lazarfeld (55) asked 100 women to state their preferences among silk and rayon fabrics. In attempting to determine a common underlying element of meaning they grouped the comments into two groups of subjective attributes labeled "relaxing" and "demanding". The term relaxing encompassed the following comments:

smooth, silky
fine, finer quality
even, threads don't stand out so much, even in the nap,
closer texture
soft, pliable, melts in your hands, clings more
sheer, thin
more appealing, more pleasing, more comfortable
goes with delicacy, caress, frivolous, gossamer, airy, luxurious, gentler

The term "demanding" related to the following perceptions:

rougher, crepier, not quite so satiny, not quite so slippery, doesn't slip, a little more woolish, not so shiny
strong grain, looser weave, more firmly woven, coarser weave
stiffer, spring to it, more crisp, more resistance
more elastic
firmer, stronger
thicker, more substantial, more body
wear longer
more noise
more character, not neither-nor, more interesting
doesn't try to be something it isn't
don't like silks

The application of these terms was based on the amount of energy required of the judges as they perceived preference. "Relaxing" characteristics required the lesser amount of energy. Because of resistance to handling, "demanding" characteristics required a greater amount of energy for perception. This classification method yields categories of terms that are quite broad but their procedure demonstrates efforts to analyze hand preference of fabrics based on the terminology used and understood by the judges.

Howorth and Oliver (10) followed the same procedure in asking 25 judges to evaluate pairs of fabrics for preference and requesting brief reasons for their choices. Twenty-one different terms were used in the statements of preference. Of these, 86% of all decisions were made on the basis of smoothness, softness, firmness, coarseness, thickness, weight, warmth, harshness and stiffness. Measurements of physical properties determined to relate closest to the characteristics identified by the judges were also made on the fabrics evaluated. Following up with factor analysis, they found that the terms and properties grouped into factors of stiffness, roughness, thickness, and a thermal characteristic. Significant in this work is the effort to relate subjective perceptions to measurable physical properties.

Winakor et al. (65) developed polar word pairs that corresponded to the physical characteristics of stiffness, roughness, and thickness. The word pairs were tested for understanding on subjects similar to the final sensory judges. This again demonstrates the principle that terminology used in evaluation of fabric hand be familiar to the judges. A similar procedure was followed by David et al (16).

Brand (11) focused on terminology as it relates to fabric aesthetics, that is, fabric properties perceived by the senses, specifically appearance and hand. Common words were believed to be the basis for evaluating fabric aesthetics and appropriate words needed to be clearly defined. A list of eighty words describing fabric aesthetic characteristics was compiled. He recommended polar word pairs as a means of specifying fabric characteristics. He used factor analysis to determine whether a word pair corresponded to one or more factors or sensory processes in the judging process. It was believed that the factors would identify an underlying concept that could be measured objectively.

The need for terms clearly defined was recognized as early as 1940 by joint meetings of committees of the American Association of Textile Chemists and Colorists and Committee D-13 on Textile Materials of the American Society for Testing and Materials. They agreed upon a list of terms that represented both measurable physical properties as well the subjective elements of hand. The words were chosen to be "simple, understandable to the layman as well as to the engineer or scientist". Also recognized by this joint committee was that if the results of physical tests were to be compared with the hand of fabrics as judged by the experts, it was "necessary for the experts to analyze their appreciation of hand into components corresponding to physical properties. This necessitates a consciously directed effort in judging hand." The list proposed by this group (4) and eventually accepted by The American Society for Testing and Materials (6) is as follows:

Physical Property	Explanatory Phrase	Terms to Be Used in Describing the Range of the Corresponding Component of Hand
1. Flexibility........	Ease of bending	Pliable to stiff
2. Compressibility....	Ease of squeezing	Soft to hard
3. Extensibility......	Ease of stretching	Stretchy to non-stretchy
4. Resilience.........	Ease of recovery from deformation	Springy to limp
5. Density............	Weight per unit volume	Compact to open
6. Surface contour....	Divergence of the surface from planeness	Rough to smooth
7. Surface friction...	Resistance to slipping offered by the surface	Harsh to slippery
8. Thermal character..	Apparent difference in temperature of the fabric and the skin of the observer touching it	Cool to warm

Hoffman and Beste (23) noted that the words descriptive of fabric hand are usually qualitative in nature and believed that a more quantitative and reproducible system of evaluation was necessary. They discussed the following fabric properties in terms of physical terms which could be precisely measured: stiffness, compliance, liveliness, weight, leanness and bulk, compressibility and thickness, waxiness, friction, contact warmth, drape, smoothness and luster, covering power, and contour retention and resilience.

Harada et al. (21) compiled a list of "raw descriptive words" which were selected from English and Japanese hand terminology. They then related these words to basic hand terms that could be mechanically defined and physically measured. They tested the validity of their definitions of terms by correlation with the associated tests. They found that the replacement of raw descriptive terms with terms closely related to physical properties made the mechanical meaning of hand easier to understand. As has been seen in other studies, this allowed for the large number of common words to be reduced to a smaller number of specifically defined terms. The results of their work parallels that of Kim and Vaughn (34) in which they surveyed the literature and summarized objectively measurable physical parameters with associated hand terms.

One component of Kawabata's (29) effort to standardize the process of hand evaluation involved the specification of terminology. In observing expert judges he noted that they made judgments concerning the overall hand or quality of fabric based on "primary" hand values or properties. Depending upon its specified end use, a fabric was rated on three to six properties such as KOSHI (stiffness), NUMERI (smoothness), FUKURAMI (fullness and softness). Kawabata and his coworkers used statistical methods to link these terms to objective measurements and to relate them to the total hand value assigned to a fabric.

Biases have been encountered in adapting the Kawabata hand evaluation system across nations and cultures which are evident in both of the translation stages of the evaluation process. In the first stage, the basic mechanical properties are sensed or measured and are then translated into primary hand values. The descriptors given these primary hand values are Japanese words that are often not understood by people working with the system in other parts of the world.

Considerable work has been done in carefully translating and defining the terms. After working with the system for a while one tends to become adapted to a Japanese way of thinking. One also looks for the concept within the terminology and works with his own understanding. The danger in this is that in the international framework of the system there may be and probably are differences in individual as well as national understanding of some of the concepts and terms.

A more important bias that has been encountered in international adaptation of this system is in the second translation step. There are differences in how different cultural groups weight the primary hand values in order to determine the overall total hand value. A specific example is that the Japanese place high value on SHARI for men's summer suiting. SHARI is the property given fabric that has a sharp, crisp, dry surface feeling. It is thought that this property is important because of climate in Japan. Correlation of evaluation results with other countries, such as Australia, indicate that other countries do not place the same value on this property (41).

This discussion of the terminology of fabric hand indicates that it is an important consideration in the application and replication of research in subjective and objective hand evaluation.

2.3. Fabrics Used in Hand Evaluation Studies

Fabrics used in hand evaluation research have varied dependent upon the objectives of the research. Evaluation of fabric hand and tailorability has been the primary interest of a large number of research studies. It has also been one of a number of variables investigated in studies of textile processes and technology. A review of the literature shows that a variety of fabrics have been used. Woolen and worsted wool, wool blend, and synthetic suiting fabrics have been studied extensively (9, 10, 29, 36, 41, 64).

Hand evaluation and perception of softness has been an important variable in research concerning fabric softeners (5, 8, 27, 48,) and finishes (58). Fabrics used in these studies included 100% cotton, polyester/cotton woven shirting-weight fabrics, and polyester/cotton knit fabrics. Nonwoven fabrics have also been evaluated (14, 42). Studies evaluating the acceptance of flame-retardant sleepwear have included polyester, modacrylic and cordelan fabrics of plain jersey knit, terry loop-pile knit and brushed knit constructions; 100% cotton and 100% polyester woven flannels; and tricot knit fabrics of napped or smooth surfaces (33, 50, 52,). Kawabata and Niwa have extended the range of fabrics covered by their translation equations to include fabrics used in men's suiting, jackets, and slacks, women's thin dress fabrics, men's dress shirts, knitted outerwear and underwear (31).

No research has been found which has evaluated the hand of woven polyester/cotton blend bottom-weight fabrics used in men's and women's sportswear. These are fabrics that have unique characteristics in relation to hand, appearance and tailorability. The physical properties of this group of fabrics are different enough from the worsted and woolen suiting fabrics that the translation equations developed from those fabrics do not apply to the polyester/cotton fabrics even though they may be used in similar end use products. Consultation with major textile manufacturers indicates that given the market share of this class of fabrics, research is warranted in the study of the hand of polyester/cotton bottom-weight fabrics.

2.4. Selection of Evaluation Panels

The selection of subjects to serve on an evaluation panel depends on the type of evaluation the experimenter wants to have made. There are two types of test: discrimination tests and preference tests. The objective of preference testing is "to predict direction of choice and sometimes extent to which a product appeals to some population"(5). With this in mind, the only requirement for the members of a panel is that they represent a specified consumer population. These consumer judges are often referred to as "naive" judges.

In discrimination testing, panel members are often referred to as "expert" judges. They are people who have the technical knowledge, experience, and/or training which qualifies them to judge and evaluate complex stimuli. They are capable of making absolute ratings.

Both types of judges have been used in studies to evaluate the hand of fabrics. Winakor et al. (65) believed that because expert panels were able to quantify the sensory characteristics of a product, that data should be compared with physical measures. It is generally held that expert judges are experienced in evaluating fabric with the ultimate consumer in mind and that they can accurately assess the hand of fabric in relation to product end use.

The number of judges required is determined by the type of test. In preference testing there is greater variability in judgments as compared to discrimination testing. However, the main concern is that the number of judges be large enough to be representative of the population. It has been recommended that there be at least 30 panelists (5).

The number of panel members recommended for discrimination testing is usually ten and no fewer than five (1). The number actually depends on the type of product as well as how many "experts" are available. No study has been found in which statistical methods have been used to systematically determine the number of judges that should be used in hand evaluation studies.

There are several factors to consider when using a test panel. These include physiological sensitivity, motivation of subjects and other psychological factors. The experimenter should be aware of them so that evaluation procedures can be designed to eliminate or at least control for any which will bias test results.

2.5. Objective Evaluation of Hand Attributes.

Peirce (53) was one of the first to discuss the hand of fabrics in terms of properties that could be physically or mechanically measured. He quantified the stiffness of fabrics by using a flexometer to determine bending length and, from this measurement, derived flexural rigidity and bending modulus.

Dreby, in his work with soft finished fabrics (18), identified flexibility, surface friction and compressibility as the most important components of fabric hand. He developed the Planoflex to measure pliability in the form of shear deformation. He developed the Friction-Meter to determine the coefficient of friction between two pieces of fabric. The Compression-Meter was also developed by Dreby to measure the compressibility of fabrics.

A comprehensive measure of fabric hand was developed by Alley and McHatton (2) and revised by Alley (1). In this method, fabric is pulled through a nozzle by an Instron tensile tester. From the resulting stress-strain curve a quantity called the "handle modulus" is calculated as a function of the geometry of the nozzle, and the thickness and coefficient of friction of the fabric.

Vaughn and Kim (34) identified ten components of fabric hand that can be physically measured. These are drape, friction, hand, shearing, smoothness, softness, stiffness, tensile properties, thickness, and warmth. They summarized these components and related test methods in tabular form as shown in Table 1. As the research literature in this field of study indicates, there are varieties of methods, equipment, degrees of fabric deformation and final parameter form that have used.

Matsuo, et al. (43) listed the following basic elements of hand: weight, thickness, bending, compression, shearing, stretching and friction. Each element was described by several mechanically measured properties. For example, the element of bending was separated into bending rigidity and bending recovery. Bending rigidity was expressed as bending resistance at large deformation, bending slope, bending hysteresis width, shearing slope and shearing hysteresis width. Bending recovery was expressed as bending hysteresis width at large deformation and instantaneous bending recovery time. For the most part the testing equipment they used to objectively measure the related mechanical properties were among those listed by Kim and Vaughn (34)

Table 1. Mechanical Measures of Hand Parameters

Parameter	Test Method & Apparatus	Form of Result
Hand	Handle-o-meter Fabric-o-meter	Force to deform a fabric
Drape	M.I.T. Drape-o-meter F.R.L. Drapemeter Cusick Drape Tester	Drape coefficient Drape length Number of nodes Shape factor of nodes Drape coefficient
Friction	Tester	Coefficient of static friction Coefficient of kinetic friction Frictional force-displacement curve
Shearing	Planoflex 45° to Warp & Filling Mörner & Eeg-Olofsson Behre's Tester	Deforming angles at creasing Load-elongation curve Shearing force-shearing angle curve Shearing hysteresis curve
Smoothness	Roughness Test Bekk or Sheffield Paper Smoothness Tester Frictional Method Comparison with Smoothness Standards	Roughness Index Bekk Seconds or Sheffield Numbers
Softness	Schiefer Compressometer Thickness Gauge	Thickness-Pressure Curve Hardness
Stiffness	Flexometer Planoflex Clark Stiffness Tester Gurley Stiffness Tester Olsen Stiffness Tester Shirley Stiffness Tester Shirley Cyclic Bending Tester	Bending length Bending modulus Flexural rigidity Force-deflection curve Bending hysteresis curve Bending hysteresis curve Bending hysteresis curve

Table 1. Mechanical Measures of Hand Parameters, continued.

Parameter	Test Method & Apparatus	Form of Result
Tensile Property	Tester	Load-elongation curve Extensibility Compliance
Thickness	Gauge Schiefer Compressometer Micrometer Dial Gauge	Standard Thickness Thickness-pressure curve
Warmth	Guarded Hot-Plate Density Method Cover Factor Method	Heat Flow in Btu. Compactness Cover Factor

and given in Table 1. Japanese standard test methods were followed.

These same mechanical properties were chosen by Kawabata (28) in the work he has done in evaluating the hand of fabrics. Each property is described by two or three characteristic parameters which were selected to describe the property thoroughly. These properties are listed in Table 2. with the defined parameters.

Kawabata also developed instruments to be used in the measurement of these specific fabric properties (28). The measurement principles are the same as those followed in the traditional methods used up to this point in measuring mechanical properties of fabrics. The machines were designed specifically for the objective evaluation of fabric hand and the deformation force applied is of the magnitude applied when a fabric is manipulated and evaluated by the human hand. This is in contrast to methods such as a tensile test that takes a fabric to break during the measurement process. These Kawabata Evaluation System

Table 2. Definition of KES Parameters

Mechanical Property	Parameter	Description
I. Tensile	1. LT	Linearity of load-extension curve (-)
	2. WT	Tensile energy (gf·cm/cm²)
	3. RT	Tensile resilience (%)
II. Shear	4. G	Shear rigidity (gf/cm·degree)
	5. 2HG	Hysteresis of shear force at 0.5 degrees (shear angle) (gf/cm)
	6. 2HG5	Hysteresis of shear force at 5 degrees (gf/cm)
III. Bending	7. B	Bending rigidity (gf·cm²/cm)
	8. 2HB	Hysteresis of bending moment (gf·cm/cm)
IV. Compression	9. LC	Linearity of compression-thickness curve (-)
	10. WC	Compressional energy (gf·cm/cm²)
	11. RC	Compressional resilience (%)
V. Surface Characteristics	12. MIU	Coefficient of friction (-)
	13. MMD	Mean deviation of MIU (-)
	14. SMD	Geometrical roughness (micron)
VI. Fabric Construction	15. W	Fabric weight per unit area (mg/cm²)
	16. T	Fabric thickness (mm)

(KES-F) instruments were designed to allow fast reproducible measurements, with output in digital as well as graph form.

2.6. Correlation of Objective and Subjective Evaluation Methods

One of the goals in studying the relationship between objective and subjective evaluation of fabric hand is the elimination of the human judge from the process. In the field of sensory evaluation, this goal has already been reached in the area of color measurement. A final step in this type of process involves determining the relationship between objective measurements of fabric properties and the hand attribute scale values determined subjectively. Mathematical models have been developed by several researchers to examine experimental data and to use the information to predict hand attribute values from objective measurements only.

Lundgren (39) related subjective and objective measurements of hand attributes by a mathematical model of the form:

$$H = R_R S_R + R_S S_S + R_C S_C = R_T S_T$$

where H represents the value of the hand attribute being evaluated, R represents the judge's response to perception of S, the stimulus defined by the mechanical or physical measurement of the attribute. The subscripts R, S, C, and T, refer to the stimulus attributes of roughness, stiffness, compactness and thermal character respectively. The solution of the equation assigned numerical values to the R coefficients indicating the weights given to each stimulus attribute. Lundgren used the coefficients to construct a plus-minus response profile. A negative coefficient was taken to indicated that the opposite of the stimulus attribute measured was preferred. He used this procedure to describe the hand of fabrics in specific groups defined for the study and proposed that the method could be used to guide the development of fabrics to meet consumers preferences.

The mathematical model proposed by Matsuo, et al. (43) to relate objective and subjective hand attributes was based on the Weber-Fechner law which related a stimulus S and its associated subjective response R by the following equation:

$$R = K \triangle S/S.$$

By replacing $\triangle R$ with $\triangle Y_i$, the measured value of a hand attribute, and replacing $\triangle S/S$ with $\triangle X_i/X$, the percent difference in physical property that a human can detect, the following relationship was derived:

$$Y_i = (2.30)/\alpha_i)(\log_{10} X_i/X_{si})$$

where X_i is defined as the measured value of the physical property for the fabric, X_{si} is the measured value of the physical property for a standard fabric and α_i is the subjective measure of the hand attribute. This equation was used to calculate value of the hand attributes by which fabrics were compared.

Kawabata (28) proposed linear relationship between the sixteen physical parameters of a fabric measured with his evaluation system and the hand attribute value assigned to that fabric by a panel of judges. He correlated each hand value with the measured physical values and obtained equations of the form

$$Y = C_0 + \Sigma_i C_i X_i$$

where Y is the primary hand value, C_0 and C_i are constants (i = 1-16), and X_i are normalized values of the mechanical properties. Kawabata grouped the sixteen mechanical properties into blocks of tensile, shear, bending, compression, surface and fabric construction properties (refer to Table 2). In developing the prediction equation for each primary hand attribute and the measured properties he used a method of stepwise-block regression to avoid correlation effects of variables within the blocks of properties.

For each proposed fabric end use a large representative group of fabrics was evaluated. For example, in the case of men's winter suiting fabrics two hundred different fabrics were evaluated. The coefficients obtained are now used to predict the primary hand values of new fabrics. The correlation of predicted hand attribute values and subjectively measured values obtained for a new group of men's suiting fabrics was between .78 and .93.

The evaluation of hand also involves an overall assessment of a fabric from the standpoint of how it is valued for a specified end use. Kawabata used the term Total Hand Value to identify this overall judgment. He developed a prediction or translation equation for each group of fabrics by correlating experts evaluation of primary hand attributes and total hand. He used multivariate regression to obtain the following equation:

$$THV = C_O + \Sigma_i Z_i$$

where

$$Z_i \text{ equals } C_{i1}(Y_i - M_{i1})/\sigma_{i1} + C_{i2}(Y_i^2 - M_{i2})/\sigma_{i2},$$

and i identifies the primary hand values, Y_i represents the primary hand value of the ith primary hand, C_O, C_{i1}, and C_{i2} are constants and M and σ are the mean and standard deviation of the respective primary hand values. For a new group men's winter suitings, the correlation between the calculated total hand values and those determined by judges was .74.

3. RESEARCH OBJECTIVES

The purpose of this research project is two-fold. There is the recognition of the need for a systematic study of subjective methods or protocols that are used to assign scale values to fabrics which reflect the degree to which they are perceived to possess a specified hand attribute. One purpose of this study will be to work with a group of polyester/cotton woven bottom-weight fabrics in evaluating selected subjective scaling methods. The selected methods will be rating scale, ranking, and paired comparison.

It is also necessary to expand the work that has been done in correlating subjective and objective measurements of fabric hand properties to a wider range of fabric groups. Polyester/cotton woven bottom-weight fabrics comprise a group of fabrics that have yet to be studied. The second purpose of this project will be to correlate scale values for specified primary and total hand attributes with measures of related physical and mechanical properties of these fabrics.

The specific objectives of this study are:

1) To select attributes that are consistent with terminology used in the textile industry to describe the hand of polyester/cotton woven bottom-weight fabrics.

2) To determine which of the selected scaling methods is the most valid, most reliable and most efficient when the hand attributes of polyester/cotton bottom-weight fabrics are subjectively evaluated.

3) To develop though statistical regression techniques translation equations that use objective property measurements to predict the hand values of polyester/cotton bottom-weight fabrics.

4. METHODOLOGY

4.1. Test Fabrics.

4.1.1. Selection of Fabrics.

Twenty-seven polyester/cotton blend fabrics were selected from the current line of fabrics being marketed by a major textile manufacturer. The specified end use of these fabrics is men's and women's bottom-weight sportswear. The selection was made in consultation with marketing, product development and research and development personnel who work with this line.

Plain, twill, oxford and sateen weaves are represented. Blend levels include 25/75, 40/60, 65/35, 80/20 polyester/cotton and 100% cotton. The fabric weights range from 4.6 to 7.8 oz/yd^2.

It will be noted that the original selection of fabrics contained twenty-eight styles. One fabric, project code number 8, was shipped yardage short and was therefore not included in the study.

4.1.2. Grouping of Fabrics.

The twenty-seven fabrics were assigned to three groups of nine fabrics by the following procedure. The fabrics were first assigned to stratified groups by ordering them according to weight.

Fabrics were randomly selected from each of the weight groups and placed in the final three experimental groups. The assignment of fabrics into groups was subsequently checked to assure a representative distribution of properties in each group. The fabrics were evaluated in the same groups of nine fabrics throughout this study. The fabrics are described in Tables 3.1, 3.2 and 3.3.

4.1.3. Fabric Samples and Test Conditions.

The samples for subjective evaluation procedures were cut to measure 12 x 15 inches. For objective test procedures fabric samples measured 20 cm^2.

Before subjective or objective testing, samples were conditioned for a minimum of twenty-four hours at 20±2° Celsius and 35±2% relative humidity. All testing procedures were performed under these same environmental conditions.

4.2. Terminology and Description of Hand Attributes.

A terminology survey was sent to approximately twenty-five people who work or have worked in either the marketing or the development of polyester/cotton woven fabrics. The survey consisting of 111 terms used to describe fabric hand was compiled from the literature (see Appendix A.) The survey asked each person to look over the list provided and circle the words used in describing the hand of polyester/cotton bottom-weight fabrics. The respondents were then asked to briefly define the circled terms and to indicate which of the following fabric properties is most closely related to the term as it is used:

Table 3.1. Fabric Group 1.

Fabric Code #	Weave	Blend (Poly/Cotton)	Weight (oz/yd^2)
1	Plain	25/75	6.0
2	Twill	25/75	6.6
7	Plain	40/60	5.5
10	Plain	40/60	5.7
16	Twill	65/35	7.0
17	Oxford	65/35	6.3
20	Twill	00/100	7.9
23	Sateen	75/25	5.2
27	Twill	80/20	5.1

Table 3.2. Fabric Group 2.

Fabric Code #	Weave	Blend (Poly/Cotton)	Weight (oz/yd^2)
4	Plain	40/60	5.5
9	Oxford	40/60	6.5
11	Oxford	40/60	6.3
15	Plain	65/35	4.8
18	Twill	00/100	6.0
19	Twill	00/100	6.9
21	Twill	75/25	5.3
22	Twill	80/20	6.4
24	Twill	65/35	6.6

Table 3.3. Fabric Group 3.

Fabric Code #	Weave	Blend (Poly/Cotton)	Weight (oz/yd^2)
3	Oxford	25/75	6.6
5	Twill	40/60	7.0
6	Oxford	40/60	6.6
12	Plain	40/60	5.6
13	Plain	40/60	5.4
14	Oxford	40/60	6.3
25	Oxford	65/35	6.1
26	Sateen	60/40	5.4
28	Plain	80/20	4.6

Flexibility
Compressibility
Extensibility
Resilience
Shearability
Density
Thickness
Weight
Surface Contour
Surface Friction
Moisture Regain
Thermal Character
Overall Fabric Hand

The identified terms, definitions and related fabric properties were analyzed with the purpose of selecting terms that can be designated as hand attributes of polyester/cotton woven bottom-weight fabrics. The goal was to select terms that are easily and universally understood, and measurable by objective methods.

4.3. Panel of Judges.

Eleven judges were recruited from among personnel of a major United States textile manufacturing company. All were male and their ages ranged from 36 to 63 years. Their experience included manufacturing, marketing, quality control, and/or product development of woven textiles, including polyester/cotton bottom-weight fabrics. They were designated "expert" judges. Demographic data of the judges is presented in Appendix B.

Prospective judges were screened to eliminate physical factors that would limit their effectiveness in evaluating fabric hand.

4.4. Subjective Test Procedures.

4.4.1. General Procedures.

Each judge participated in six one-hour evaluation sessions. For three days, one session in the morning and one session in the afternoon was scheduled. The days were spaced at least one week apart unless prevented by the judge's schedule.

Prior to the beginning of each evaluation session, the judges washed their hands with a nonionic bar soap (Neutrogena, Neutrogena Corporation) and dried them with a terry cloth towel. They were allowed to wash their hands again during a session if they desired. They were also encouraged to stand, stretch, or relax whenever they felt necessary.

During evaluation sessions, judges were seated at a table. A screen allowed free handling of fabrics but prevented the fabrics from being seen.

Three scaling methods were used to evaluate five fabric hand attributes: rating scale, rank order, and paired comparison. On a given day, a judge evaluated the hand of one set of fabrics, evaluating all five attributes by the three methods.

Two formats were followed for a day's evaluation sessions. One consisted of rating scale evaluation of five attributes and paired comparison evaluation of three attributes. The second involved the rank order evaluation of five attributes and paired comparison evaluation of two attributes. The two formats were used to keep the time for one session within an hour.

The order of scaling methods within a session was randomized, however, during each one-hour session, one method was always completed for all attributes before the second was started. For example, a typical session consisted of a judge evaluating the nine fabrics in a group for each of five attributes by the rating scale method, and then proceeding to evaluate the fabrics for three attributes using the paired comparison method. The order of evaluation of attributes was also randomized within the two sessions of a particular day.

4.4.2. Rating Scale.

The nine fabrics in a group were presented to the judge one at a time. The judge was asked to assign to the fabric a number on a scale of one to nine. The number reflected his perception of the degree to which the fabric possessed the attribute being evaluated. For each attribute the end-points on the scale were defined. A fabric perceived to possess the attribute to a small degree would be assigned a "1" and a fabric perceived to possess an attribute to a large extent would be assigned a "9". The ratings assigned to each fabric were recorded by the experimenter.

The ratings recorded for an attribute were averaged across judges to give scale values for each fabric in a set. The interval scale values obtained were used in further analysis of the data. These procedures were followed with each set of fabrics.

4.4.3. Ranking.

One group of nine fabrics was presented to a judge all at one time. The judge was asked to rank and lay out the samples in the order of degree to which the attribute was perceived in each fabric. The ranks of the fabrics were recorded by the experimenter so that the fabric perceived to possess the attribute least was assigned a number one. The fabric perceived to possess the attribute to the greatest extent was assigned the rank of nine. The rank values obtained for each fabric within a set was converted to interval scale by the method of started-and-folded logs (38). For each judge, the fabrics were ranked in forward and backward directions. The value of 1/3 was subtracted from each of the forward and backward ranks. The difference between the natural logarithms of the new values gave interval scale values for the fabrics ranked according to the specified hand attribute. The formula for this re-expression is as follows (38):

$$\text{rank order scale value} = [\log_n(i-1/3)-\log_n(n+1-i-1/3)]$$

where n is the number of fabrics ranked and i is the rank assigned to a specific fabric.

The re-expressed values were averaged across judges and the values were used in further data analysis. These procedures were followed for each hand attribute evaluated and for each fabric group.

4.4.4. Paired Comparisons.

For a group of nine fabrics there are thirty-six pairs of samples. They were presented to a judge one pair at a time. The judge was asked to select the fabric perceived to possess the attribute to the greater extent. The experimenter recorded "1" for the fabric chosen and "0" for the other. The order of presentation of pairs was randomized for each attribute and each session.

4.4.3.1. A preference matrix was constructed from the data for all judges. Interval scale values for the data were derived by the method described by Thurstone (47). In this method the values in each cell are expressed as the proportion of judges who preferred the column fabric over the row fabric. Diagonal were assigned given the value of .500, a step that makes the assumption that a fabric would be chosen over itself fifty percent of the time.

The proportions were transformed to normal deviates. SAS procedure PROBIT was used for this transformation (57). The normal deviates were summed over each column. The average for each column was obtained by dividing each sum by the number of fabrics. A final scale of positive scale values was obtained by adding the positive value of the lowest possible negative average which is 3.791. These scale values were used in further data analysis. These procedures were followed for each hand attribute evaluated and for each group of fabrics.

4.4.3.2. The method of scale derivation outlined by Thurstone eliminates the judge as a variable. Because judge to judge variability is a factor taken into consideration in the analysis and estimation of reliability, a variation of Thurstone's method was used to derive scale values for the fabrics as evaluated by the paired comparison method.

The procedure followed was to construct a matrix for each judge. A cell contained "1" if the column fabric was chosen over the row fabric and "0" if the column fabric was not chosen. The diagonal cells were assigned .500 as before. The columns were summed to give the number of times the judge chose the column fabric over the other fabrics in the set. The column sums were divided by nine to give the proportion of times the fabric was preferred over the other eight. The SAS PROBIT function was used to transform the proportions to normal deviates. The normal deviates were averaged across judges to give scale values for an attribute for each of the fabrics in a group. This data obtained by this method was used in analysis of variance procedures.

4.4.5. Handling of Fabrics.

The following procedures were followed to guarantee that one fabric sample was handled only five times and only by the same person.

Two sets of each group of nine fabrics was prepared for each judge. One set was used by the judge to evaluate all five attributes by the rating scale method. The other set was used by the judge to evaluate all five attributes by the rank order method.

For the paired comparison method, a set of fabrics of each group was prepared consisting of all thirty-six possible pairs of samples. One set was used by a judge to evaluate all five attributes.

4.5. Scaling Method Validity and Reliability.

A multitrait-multimethod matrix consisting of the intercorrelations between values obtained for the five attributes evaluated by three methods was constructed for each of the three fabric groups. This method of correlational analysis has been discussed by Campbell and Fiske (12). It examines the correlations between all combinations of method/trait measurements in order to evaluate the convergent and discriminant validity, trait variance and method variance.

Reliabilities expressed as measures of internal consistency were derived separately by analysis of variance procedures. The reliability coefficient, r_{SP}, is the expected correlation of one eleven-judge evaluation with the evaluation of another eleven-judge panel drawn from the same source. The reliability coefficients are placed on the main diagonal of the multitrait-multimethod matrix.

Predictive validity was determined by the correlation of a subjective measure of an attribute with the physical measure of the same attribute.

4.6. Objective Test Procedures.

The Kawabata Evaluation System was used to measure physical properties of the twenty-seven test fabrics. Weight, bending, shear, compression, surface and tensile characteristics were measured in the order just presented. Three samples of each fabric were tested. One test per sample was performed in each of the warp and weft directions for bending, shear and tensile. For compression one test was performed on each sample, and for the surface test two tracks per sample per direction was performed.

From these test measurements, the values for the sixteen properties were calculated. Warp, filling and average values are presented in Appendix D.

4.7. Correlation of Objective and Subjective Measurements.

Stepwise regression techniques were used to determine coefficients to be used in predicting hand attributes of polyester/cotton woven bottom-weight fabrics. The SAS statistical analysis system was used in the computer analysis. The sixteen parameters measured by Kawabata instrumentation were regressed on the primary hand attributes to give coefficients for linear prediction equations as follows:

$$Y = C_0 + \Sigma_i \, C_i \, Y_i$$

where Y is the primary hand value, C_0 and C_i are constants (i = 1-16), and X_i are values of the mechanical properties.

The primary hand attributes were regressed on the overall hand attribute to give coefficients that will be used in for prediction equations in the form:

$$THV = C_0 + \Sigma_i \, Z_i$$

where Z_i equals $(C_{i1} \, Y_i + C_{i1} \, Y_i^2)$, i identifies the primary hand attribute, and C_0, C_{i1}, and C_{i2} are constants.

The translation equations for primary and total hand values will be determined from the data of each group of fabrics and cross-validated with the data from the other two fabric groups.

5. RESULTS AND DISCUSSION

5.1. Terminology.

5.1.1. Terminology Survey.

Of the 25 surveys distributed, 14 were completed and returned. Eleven of those returned were filled out as directed and were used in further analysis.

5.1.1.1. Terms Identified and Defined. The terms recognized by respondents as having been used to describe the hand of polyester/cotton bottom-weight fabrics are listed in Appendix A, Table A.1. Accompanying each term are the definitions as written by the respondents.

Of the 111 terms presented in the survey, 75 were circled by one or more respondents. The terms that were identified by at least 50% of the respondents were chosen for further analysis. They were boardy, body, cottony, crisp, drapeable, firm, hairy, harsh, raspy, dry, soft and thin.

The definitions of boardy, crisp, drapeable and firm related in general to fabric stiffness. Drapeable meant flexible and not stiff, while boardy, crisp and firm meant stiff and resistant to bending.

Hairy, harsh, raspy and dry were, for the most part, related to the evaluation of the fabric surface. Definitions of harsh and raspy had negative connotations related to coarse or rough. Hairy was used to describe a fuzzy surface of too many raised fibers while dry referred to a thin, not-smooth surface feeling.

The descriptions of cottony and soft were very much the same and related to fabrics that are smooth, compressible and not stiff. In several cases soft was used to define cottony and vice versa.

Body was related to a combination of thickness and weight that would give a fabric a desired degree of firmness. Thin was used to describe a fabric lacking body. It also described the thickness of areas of a piece of fabric or a fabric as a whole.

5.1.1.2. Terms Related to Fabric Properties. The respondents were asked to indicate which fabric property was most closely related to the term as they use it in describing the hand of polyester/cotton bottom-weight fabrics. However, most indicated that more than one property related to the term as they had defined it. The fabric properties are given in Appendix A, Table A.2. with the related terms listed below each.

Fifteen or more terms were related to flexibility, compressibility, resilience, density, thickness, weight, surface contour, surface friction, and overall fabric hand. In most cases there was consistency between the definition of the terms and the properties that the terms were related to. For example, boardy, crisp, drapeable, firm, flimsy, papery and limp were related to flexibility which concurred with the definitions. In all, there were 24 terms related to flexibility.

Twenty-four terms were also attributed to the fabric property of compressibility. There was not a strong indication of a relationship evident from the definitions. Boardy was assigned by three respondents, however only one definition specifically used compressibility. It was difficult to derive compressibility from the other definitions of the term boardy. Also related to compressibility were cottony, crisp, firm, spongy and thin.

Resilience was related to 22 terms. It was specifically stated or implied in the definitions of bloom, body, bounce, cottony, dead, lively, rubbery, silky, and springy. In some definitions it appeared that words such as flexible, body, firm, flimsy and limp were used to represent resilience.

The fabric properties of density, thickness and weight had 17, 16, and 18 terms related respectively. Ten terms were common to all three properties. They are body, bulky, crisp, full, heavy, hungry, lofty, sleazy, thick and thin. The close relationship between these three properties in the specification of hand terminology reflects the interrelationship between these properties in the actual physical characterization of fabrics. They are closely related physically and were also closely related in the respondents under- standing and use.

The respondents attributed 20 terms to the property of surface contour and 31 to surface friction. The terms related to surface contour included coarse, cottony, fuzzy, hairy, kind, raspy, rubbery scratchy, slick, smooth, soft, velvety and wooly. These ten words were also on the list for surface friction as were bristly, crisp, greasy, oily, quiet, scroopy, soapy and warm. The distinction between surface friction and surface contour does not appear to be clear to the respondents. Slick was defined to have a 'smooth, greasy surface' which involves concepts of both contour and friction. A fabric that is raspy has a coarse, harsh surface "like emery cloth" and therefore would have high surface friction. The relationship indicated by the respondents' definitions was that a fabric that had a rough surface had high surface friction and a smooth surface had low surface friction.

Because the respondents related the terms that they had defined to more than one property, it is difficult to discuss the "overall fabric hand" classification separately. Thirty terms were related to this category, however all had been related to at least one of the other fabric properties. If one examines the terms related to overall fabric hand in relation to the other twelve fabric properties, it is possible to see the relationship between fabric properties and overall fabric hand of polyester/cotton bottom weight-fabrics. The number of terms related to the overall hand of fabrics that are also related to each of the fabric properties are charted in Figure 1. The chart

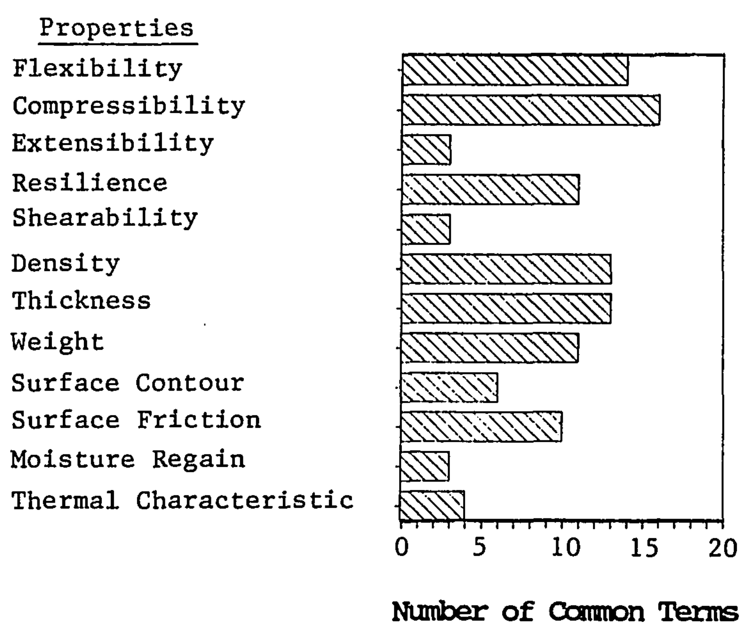

Figure 1. Number of Terms Common to Fabric Properties and Overall Hand.

shows that flexibility, compressibility, resilience, density, thickness, weight, and surface contour and friction appear to have the most influence on the judgment of the overall fabric hand of a polyester/cotton bottom-weight fabric.

5.1.2. Selection of Terminology.

The purpose of the terminology survey was to obtain information that would be used to guide the selection of attributes that would be consistent with the terminology used in the textile industry to describe the hand of polyester/cotton woven bottom-weight fabrics. In order to meet the objectives of this study, the chosen attributes had to be understood by the hand evaluation judges and clearly definable. In order to determine predictive validity, they had to be measurable by physical methods. It was therefore necessary to link terminology that is essentially trade vernacular to physical and mechanical properties of fabrics. The properties that were related by the respondents to hand terminology and to the overall hand of polyester/cotton bottom-weight fabrics were flexibility, compression, resilience, density, thickness, weight, and surface contour and friction.

The amount of time that the judges were able to give to this study restricted the number of attributes that could be evaluated to a total of five. Flexibility, surface contour, weight and thickness were selected as 'primary attributes' in the manner that Kawabata designated them. Flexibility and surface properties were indicated by the judges to be important in evaluating the hand of polyester/cotton bottom-weight fabrics. They are measurable physical properties. Bending rigidity (B) was specified as the physical measure of flexibility and surface contour was measured by surface roughness (SMD).

Because thickness and weight are closely related physically and were closely related in the definitions of terms obtained in the survey, both were selected in order to obtain information concerning the judges' perception of these properties. Thickness (T) and weight (W) are also measurable properties. The physical measurements of these four properties were made using the Kawabata Evaluation System.

The suitability of the fabrics for use in men's summer dress slacks was selected as the attribute to characterize the overall hand of the fabrics. The overall or 'total' hand is used as a summary judgment of the fabric as acceptable or unacceptable and is specific to an end use. Men's summer dress slacks were chosen because they are made from polyester/cotton blend fabrics and they are a generally recognized apparel product. In contrast to casual slacks, there are fewer style variations in dress slacks to confuse the judges' decisions.

The selected attributes are defined in Table 4. Polar directions and numerical values for the scale of each attribute are indicated for the subjective evaluation methods.

Table 4. Definitions of Selected Hand Attributes.

ATTRIBUTE	DEFINITION
Flexibility	Describes how a fabric bends. If the fabric bends easily it is pliable; if a fabric resists bending it is stiff. most pliable = = 1 or low most stiff = 9* or high
Surface Contour	Describes the divergence of a fabric surface from planeness. A smooth fabric has an even surface free from irregularities or projections; a rough fabric has an uneven surface with irregularities and projections, such as bumps or ridges. most smooth = 1 or low most rough = 9* or high
Weight	Describes the heaviness of a fabric. lightest = 1 or low heaviest = 9* or high
Thickness	Describes the distance between the top surface of the fabric and the bottom surface of the fabric. If this distance is small the fabric is thin; if this distance is large the fabric is thick. thinnest = 1 or low thickest = 9* or high
End-use Suitability	Describes the suitability of a fabric for the specified end use: Men's Summer Dress Slacks. least suitable = 1 or low most suitable* = 9 or high

* indicates the fabric the judges were instructed to select from each paired comparison pair

5.2. Subjective Method Validity and Reliability.

One objective of this study was to evaluate the validity and reliability of methods used to subjectively measure the hand of fabrics. Of specific interest were predictive, convergent and discriminant validity, and reliability expressed as a measure of internal consistency. Convergent and discriminant validity are discussed through the analysis of correlation matrices constructed of values obtained by correlation of the measurements of five hand attributes subjectively evaluated by each of three methods. Calculated reliability coefficients are also presented in these matrices.

Predictive validity is determined by the correlation of a subjective measure of an attribute with a physical measurement or criterion of the same attribute. The scale values obtained from the judges' evaluation of flexibility, surface roughness, weight and thickness were correlated with corresponding physical measurements. Predictive validity is discussed in relation to these correlations.

5.2.1. The Multitrait-Multimethod Matrix.

The subjective evaluation of one fabric hand attribute by one method is treated as one attribute-method measurement. For example, flexibility evaluated by the paired comparison method was one measurement and resulted in a scale value for each of the fabrics in a group. It follows that fifteen attribute-method measurements were obtained when the five attributes were each evaluated by the three methods.

Correlation matrices were constructed from Pearson product-moment correlations calculated between the fifteen method-attribute scales. One matrix was constructed for each fabric group and these are presented in Tables 5.1., 5.2. and 5.3. This type of correlation matrix is referred to as a multitrait-multimethod matrix (12). Because of the way in which the matrix is arranged, it is possible to assess the convergent and discriminant validity, and reliability of measurement methods, as well as method and trait variance.

The assessment of convergent and discriminant validity, reliability, and method and trait variance involves the examination and comparison of four separate regions within the multitrait-multimethod matrix. The first region consists of reliability coefficients placed on the main diagonal of each matrix. These are the values in parentheses. There are three reliability diagonals in each matrix. The reliability coefficients are expressed as measures of internal consistency and were calculated using the general form of the Spearman-Brown Prophecy formula (47). For further explanation and calculation of the reliability coefficients see Appendix E.

Different trait-same method correlations are located within solid lines next to the reliability diagonals. The values are the correlations between the scale values of two traits, such as flexibility and surface roughness, measured by the same method. Together, a reliability diagonal and a same method-different trait triangle make up a what is referred to by Campbell and Fiske (12) as a monomethod block. There are three of these blocks in each matrix.

Located within dotted lines are the different trait-different method correlation coefficients. For example, the correlation between

Table 5.1. Multitrait-Multimethod Matrix for Fabric Group 1.

	Traits	A_1	B_1	C_1	D_1	E_1	A_2	B_2	C_2	D_2	E_2	A_3	B_3	C_3	D_3	E_3
		Method 1					Method 2					Method 3				
Method 1	A_1	(.97)														
	B_1	.96	(.96)													
	C_1	.81	.76	(.96)												
	D_1	.67	.64	.95	(.92)											
	E_1	-.37	-.50	-.54	-.62	(.58)										
Method 2	A_2	.99	.95	.83	.68	-.32	(.98)									
	B_2	.96	.97	.72	.58	-.44	.96	(.96)								
	C_2	.78	.70	.98	.95	-.54	.78	.67	(.97)							
	D_2	.78	.68	.97	.94	-.43	.78	.63	.99	(.97)						
	E_2	-.82	-.90	-.59	-.55	.60	-.78	-.84	-.57	-.54	(.81)					
Method 3	A_3	.97	.93	.83	.68	-.30	.97	.91	.79	.79	-.73	(.98)				
	B_3	.92	.98	.70	.56	-.56	.89	.95	.64	-.59	-.90	.86	(.98)			
	C_3	.70	.69	.96	.96	-.63	.71	.61	.94	.91	-.57	.73	.64	(.93)		
	D_3	.62	.55	.91	.88	-.39	.65	.50	.87	.89	-.43	.63	.51	.91	(.93)	
	E_3	-.77	-.81	-.82	-.83	.78	-.73	-.74	-.81	-.77	.86	-.72	-.81	-.86	-.71	(.90)

Method 1: Rating Scale (RS)
2: Rank Order (RO)
3: Paired Comparison (PC)

Trait A: Flexibility (FLEX)
B: Surface Roughness (SURF)
C: Weight (WGT)
D: Thickness (THK)
E: End Use Suitability (ENDU)

Table 5.2. Multitrait-Multimethod Matrix for Fabric Group 2.

		Method 1					Method 2					Method 3				
	Traits	A_1	B_1	C_1	D_1	E_1	A_2	B_2	C_2	D_2	E_2	A_3	B_3	C_3	D_3	E_3
Method 1	A_1	(.95)														
	B_1	.86	(.93)													
	C_1	.45	.07	(.93)												
	D_1	.49	.04	.94	(.94)											
	E_1	-.73	-.33	-.72	-.85	(.51)										
Method 2	A_2	.98	.91	.35	.38	-.66	(.95)									
	B_2	.83	.96	.13	.12	-.37	.89	(.96)								
	C_2	.36	-.04	.95	.95	-.69	.26	.06	(.97)							
	D_2	.42	.01	.99	.98	-.77	.31	.09	.97	(.97)						
	E_2	-.91	-.65	-.65	-.69	.86	-.86	-.66	-.52	-.63	(.66)					
Method 3	A_3	.97	.91	.43	.42	-.64	.99	.91	.34	.38	-.87	(.97)				
	B_3	.84	.99	.05	.02	-.30	.90	.97	-.06	-.02	-.64	.90	(.98)			
	C_3	.27	-.14	.91	.89	-.70	.18	-.12	.91	.93	-.46	.22	-.18	(.95)		
	D_3	.42	.00	.88	.96	-.77	.34	.09	.96	.93	-.55	.37	-.03	.88	(.96)	
	E_3	-.84	-.53	-.85	-.85	.88	-.77	-.56	-.79	-.83	.91	-.81	-.50	-.71	-.78	(.70)

Method 1: Rating Scale (RS)
2: Rank Order (RO)
3: Paired Comparison (PC)

Trait A: Flexibility (FLEX)
B: Surface roughness (SURF)
C: Weight (WGT)
D: Thickness (THK)
E: End Use Suitability (ENDU)

Table 5.3. Multitrait-Multimethod Matrix for Fabric Group 3.

	Traits	Method 1					Method 2					Method 3				
		A_1	B_1	C_1	D_1	E_1	A_2	B_2	C_2	D_2	E_2	A_3	B_3	C_3	D_3	E_3
Method 1	A_1	(.96)														
	B_1	.93	(.93)													
	C_1	.97	.97	(.98)												
	D_1	.97	.96	.97	(.96)											
	E_1	-.84	-.77	-.86	-.83	(.78)										
Method 2	A_2	.98	.91	.97	.95	-.84	(.97)									
	B_2	.96	.96	.96	.92	-.78	.93	(.96)								
	C_2	.94	.89	.96	.94	-.79	.98	.88	(.99)							
	D_2	.95	.93	.98	.96	-.80	.98	.91	.99	(.98)						
	E_2	-.67	-.65	-.68	-.71	.92	-.66	-.61	-.58	-.60	(.72)					
Method 3	A_3	.99	.96	.98	.97	-.87	.97	.97	.93	.95	-.72	(.98)				
	B_3	.95	.96	.93	.92	-.74	.90	.98	.84	.87	-.62	.96	(.92)			
	C_3	.98	.95	.97	.97	-.81	.97	.96	.95	.96	-.67	.97	.95	(.98)		
	D_3	.95	.91	.97	.96	-.84	.96	.90	.97	.97	-.68	.94	.86	.96	(.97)	
	E_3	-.77	-.80	-.82	-.81	.95	-.76	-.75	-.71	-.74	.95	-.83	-.74	-.78	-.81	(.85)

Method 1: Rating Scale (RS)
2: Rank Order (RO)
3: Paired Comparison (PC)

Trait A: Flexibility (FLEX)
B: Surface Roughness (SURF)
C: Weight (WGT)
D: Thickness (THK)
E: End Use Suitability (ENDU)

the subjective measurement of fabric weight by the rating scale method and the measurement of thickness by the rank order method would be found in these triangles.

Validity diagonals consist of same trait-different method correlations, such as the correlation between flexibility measured by the paired comparison method and flexibility measured by the rating scale method. A validity diagonal separates two same trait-different method triangles and together they make up a heteromethod block.

An explanation of convergent and discriminant validity, and method and trait variance in terms of the analysis of the multitrait-multimethod matrix is provided in Appendix E. The discussion of the matrices constructed from the data obtained in this study will be simplified at times by combining the trait and method abbreviated codes, located in the key for each matrix, to label a trait-method measurement. For example, ROFLEX refers to the scale values of flexibility evaluated by the rank order method and PCENDU refers to end use suitability for men's summer dress slacks evaluated by the paired comparison method. Also note that, in the following discussion, the word 'trait' will be used interchangeably with 'attribute'.

5.2.2. Convergent Validity.

Convergent validation of measurements is established when there is correlation between the subjective measurements of one trait by two different methods. These same trait-different method values are those on the validity diagonals of the multitrait-multimethod matrices. For the three groups of fabrics, the values on the validity diagonals for flexibility, surface roughness, weight and thickness were high, .89 or above, and significantly different from zero. These correlations indicate that there was agreement between measurements obtained when different, independent methods were used to evaluate the same attribute.

For the evaluation of the suitability of the fabrics for men's summer dress slacks, the correlations between different methods were lower than the values for the other four attributes. Correlations were lowest between the measurements using the rating scale method and those of the other two methods. There was less agreement between judges concerning this assessment of the fabrics. This is particularly strong for fabric groups 1 and 2. In the case of group 1, the .60 value for r(RSENDU ROENDU) was not significantly different from zero.

The relatively high correlation coefficients on the validity diagonals establish the convergent validity of the attribute measurements. The judges were subjectively measuring each fabric hand attribute in the same way with each method.

5.2.3. Discriminant Validity.

The measurement of an attribute is invalid when it correlates too highly with measurements from which it is supposed to differ. In this study, the attributes of flexibility and surface roughness were expected to be different. Fabric weight and thickness were both included in order to determine whether differences could be found in the way the judges scored the fabrics for these two traits. There are three approaches to analyzing the multitrait-multimethod matrix in order to assess the validity of the attribute-method scores.

5.2.3.1. First Approach. The correlation between measurements of one attribute by two different methods should be different and higher than the correlation between two measurements in which both the traits and methods are different. The values on the validity diagonals of the matrices should be higher than the values in the adjoining different trait-different method triangles. For fabric groups 1 and 2, the level of the correlations within the dotted triangles are generally lower than those on the validity diagonals.

There are high correlations between some of the different trait-different method measurements, however, which indicate that the judges were not distinguishing between these attributes. Across methods there are high correlations between measures of flexibility and surface roughness when evaluated by different methods. Although they are lower than the values on the validity diagonal, they are higher than the overall level within the triangle. For the fabrics in group 1, the correlation between RSFLEX and ROFLEX was .99, and r(RSSURF ROSURF) was .97. In comparison, r(ROSURF RSFLEX) was .96 and r(ROFLEX RSSURF) was .95. If there were a difference in the way the judges perceived and scaled these two fabric attributes, the correlations between the measurements would not be as high as the correlation between two measurements of the same attribute. This pattern of correlation between subjective measurements of flexibility and surface roughness is observed in all three heteromethod blocks for each of the fabric groups and indicates that fabrics perceived to be the stiffest were also the roughest. It is also possible that the judges had difficulty distinguishing between fabrics for one of the properties, and let other fabric characteristics influence their decisions. This differs from the findings of Lundgren (39) and Howorth (26). Working with suiting fabrics, both found that flexibility and surface were separate dimensions of fabric hand.

Correlations between all of the physical properties within each fabric group are presented in Tables F.1, F.2, F.3 in Appendix F. There is no significant correlation between the bending properties of the fabrics (bending rigidity (B), hysteresis of bending (HB)) and the surface properties (coefficient of friction (MIU), mean deviation of MIU (MMD) and surface geometrical roughness (SMD)).

The correlations between subjective and objective scale measurements are presented in Appendix G. For fabric sets 1 and 3 there are correlations of a significant level between the bending properties (B, HB) and the subjective measurements of surface roughness. The same pattern of correlations between bending and surface properties occurs for all three evaluation methods. The correlations between the surface properties (MIU, MMD, SMD) and subjective measurements of surface roughness were not very high. This suggests that the judges were not able to distinguish differences in the surface roughness of the fabrics.

The judges were allowed to handle the fabrics in the way that was most comfortable to them. Many of them picked up the fabrics when evaluating the surface of the fabrics. This type of handling would allow the flexibility of a fabric to influence a decision about the surface. More specific guidelines for the handling of fabrics during the evaluation of hand could give more specific information concerning perception of surface characteristics.

There are also high correlations between the measurements of fabric weight and thickness. For the fabrics in group 2, the correlation between PCTHK and ROTHK was .93, and r(PCWGT RSWGT) was .91. In comparison, measurements of these two different attributes by different methods, r(PCTHK ROWGT) and r(PCWGT ROTHK) were as high or higher, .96 and .93 respectively. This relationship between measurements of weight and thickness is found in the heteromethod blocks of the multitrait-multimethod matrices of all three fabric groups.

The correlation between the physical measurements of thickness (T) and weight (W) was significant for fabric groups 2 and 3, .78 and .84 respectively. For group 1 the correlation was .43.

There are significantly high correlations for all methods and fabric groups between the judges perceptions of weight and thickness and the physical measurement of fabric weight. This indicates that the judges were not able to distinguish between the fabrics based on thickness alone. They were better able to distinguish between the weights of the fabrics within a group. It is possible that their evaluations of fabric thickness influenced their perception of fabric weight.

The correlations involving the judges' evaluations of the fabrics for men's summer dress slacks should be analyzed and compared from a different perspective than the other attributes. Flexibility, surface roughness, thickness and weight were chosen because they were directly related to the suitability of fabrics for this end use. If the correlation of the subjective measurement of end use suitability of these attributes is at approximately the same level as the different-method end use correlations on the validity diagonals, there would be evidence that these attributes do influence the selection of fabrics for men's summer dress slacks. For all three fabric group the comparison of end use correlations within the heteromethod blocks supports the selection of these attributes.

In the matrix constructed for fabric group 3, however it should also be noted that all the correlations between the attribute measurements of this group of fabrics are very high. Correlations of measurements that should be high are high, but correlations of measurements that should be low are also high. The fabrics in this group that were perceived to be the stiffest were also the roughest, heaviest, thickest and least suitable for men's summer dress slacks. It may be possible that the judges were unable to distinguish differences for the five attributes but identified characteristics of the fabrics which did allow them to distinguish between fabrics. These other characteristics may or may not have been related to the attribute under consideration.

There is also a difference between the level of the correlations for fabric groups 1 and 2. The correlations for group 1 are generally higher than those for group 2, however not as high as those for group 3. Even though the fabrics were randomly assigned to groups and the group means and variances of the physical properties are statistically the same, the judges unexpectedly discriminated between the fabrics within each group differently.

5.2.3.2. Second Approach. The correlation between measurements of one trait that use different methods should be different and higher than measurements of two different traits that use the same method. In comparing the different trait-same method correlation values of the validity diagonals with their corresponding values in the monomethod (solid outline) triangle, the same relationship between measures of flexibility and surface roughness, and weight and thickness are found. When the same evaluation method is used, there is a high correlation between the measures of flexibility and surface roughness. For example, for fabric group 2, r(PCFLEX PCSURF) is .90, which is higher than other correlations such as r(PCFLEX PCWGT) and r(PCFLEX PCTHK) with values of .22 and .37 respectively.

In the same different trait-same method triangle, the correlation between flexibility and end use suitability was -.81 This again shows that this fabric attribute contributes to the suitability of the fabric for use in men's summer dress slacks and that fabrics most suitable are least stiff.

Thickness and weight also correlate highly when subjectively evaluated by the same method. For example, in fabric group 1, r(ROTHK ROWGT) is .99 while r(ROTHK ROSURF) and r(ROTHK ROFLEX) are lower at.63 and .78. These correlations provide evidence that the judges were not separately evaluating the attributes of thickness and weight.

5.2.3.3. Third Approach. The pattern of correlations should be the same in all the triangles within a matrix. Within the matrices for fabric groups 1 and 2 the pattern of correlations is similar. The correlation between flexibility and surface roughness is always high as is the correlation between thickness and weight. The same general correlation pattern is found between end use suitability and the other attributes, whether evaluated by the same method or by different methods.

As previously discussed, the pattern of correlations in the group 3 matrix is homogenous. The data indicates that the judges were unable to discriminate between the attributes and perhaps were using unknown criteria to guide their judgments for all five attributes.

The analysis of the correlations between subjective measures of the selected fabric hand attributes has shown that the judges were not discriminating between fabric flexibility and surface roughness or between fabric thickness and weight. The correlations involving the physical measurements of fabric surface properties provide evidence that the subjective evaluation of fabric surface roughness was not valid. The correlations involving the physical measurements of fabric weight and thickness indicate that the evaluation of thickness was not made independent of fabric weight, which is consistent with the fact that fabric weight and thickness are interdependent properties.

5.2.4. <u>Method Variance.</u>

Differences between evaluation methods are indicated when the correlation between two different traits evaluated by the same method is different and higher than the correlation between these same two traits each evaluated by different methods. This involves comparing correlation coefficients in the monomethod triangles (in solid lines) with their parallel values in the heteromethod triangles. An example from fabric group 1 would be the comparison of r(PCWGT PCSURF)=.64 with r(PCWGT ROSURF)=.61, r(PCWGT RSSURF)=.69, r(PCSURF RSWGT)=.70 and r(PCSURF ROWGT)=.64.

Within all three fabric groups there are differences between monomethod correlations and their heteromethod complements. There is no recognizable pattern however. Sometimes the same-method correlation is higher and sometimes it is lower as in the following example of the relationship in fabric group three between r(RSENDU RSSURF)=-.77 and r(ROENDU RSSURF)=-.65, r(PCENDU RSSURF)=-.80, r(ROSURF RSENDU)=-.78 and r(PCSURF RSENDU)=-.74. The variance present between these two types of correlations does not appear to be related to systematic differences between one or more evaluation methods.

5.2.5. Trait Variance.

When two attributes are different, the correlation between measurements of one attribute subjectively evaluated by two different methods is expected to be higher than the correlation between the measurements of two different attributes by different methods. As discussed previously, for fabric groups 1 and 2 there are high correlations between the subjective measurements of surface roughness and flexibility, and between the measurements of thickness and weight. In fabric group 1 the correlation between the measurements of thickness by rating scale and paired comparison methods was .88 while r(RSTHK PCWGT)=.96 and r(RSWGT PCTHK)=.91. Similarly for group 2, r(ROTHK PCTHK)=.93 and r(ROWGT PCTHK)=.93.

In fabric group 3, the variance between flexibility, surface roughness, thickness and weight was low. The judges were not differentiating between these attributes when evaluating the fabrics in this group.

5.2.6. Reliability.

The coefficients on the reliability diagonals indicate the reliability of the scale scores across judges for each of the 15 attribute-method measurement scales obtained for that group of fabrics. For each method the reliability coefficients for flexibility, surface roughness, weight and thickness are high, ranging from .92 to .99, indicating that these results would be repeated with another group of eleven judges selected from the same population.

The attribute of end use suitability has lower reliability coefficients which range from .52 to .90. There was less agreement between judges concerning the suitability of the fabrics in each group for men's summer dress slacks than there was for the other four attributes. Overall the reliability for the subjective measurements of the selected attributes by the rating scale, rank order and paired comparison methods was very good.

The correlation values on the validity diagonals were high and similar to the corresponding reliability coefficients. The correlation between the measurements of one attribute by two independently different methods would be expected to be lower than the repeated measurement of one attribute by the same method, which is what the reliability coefficient represents. The analysis of method variance concluded that there was no difference between the three methods used in this study. The similarity between the values on the validity and reliability diagonals also support this conclusion.

5.2.7. Efficiency of measurement methods.

Measures of internal consistency are listed in Table 6. The intraclass correlation , r_I, represents the proportion of variability that is common to the scale scores observed for the fabrics within a group. This value is used in the Spearman Brown Prophecy Formula to calculate the correlation coefficients, r_{SP}, that were discussed in the analyses of the multitrait-multimethod matrices.

When a desired reliability is known, a form of the Spearman Brown formula is used to determine the number of judges that would be needed to achieve that reliability. In psychometric studies, a reliability coefficient of .90 is very acceptable (47). Using the intraclass correlations obtained from the data, the number of judges required to achieve a reliability of .90 was calculated for each attribute-method measurement. These values are also presented in Table 6.

The result of low reliability in the measures of the end use suitability of the fabrics is that more than eleven judges are needed to achieve a reliability of .90. The paired comparison method is the most efficient for all three fabric groups in that fewer judges are required in order to achieve the acceptable reliability for the end use attribute.

For the fabric hand attributes of flexibility, surface roughness, thickness and weight, the most efficient method was the rank order

Table 6. Measures of Internal Consistency

Hand Attribute	Rating Scale r_{SP}	Rating Scale r_I	Rating Scale $J_{.90}$	Rank Order r_{SP}	Rank Order r_I	Rank Order $J_{.90}$	Paired Comparison r_{SP}	Paired Comparison r_I	Paired Comparison $J_{.90}$
Fabric Group 1									
FLEX	.97	.76	3	.98	.80	3	.98	.80	3
SURF	.96	.67	5	.96	.69	5	.98	.83	2
WGT	.96	.68	5	.97	.75	3	.93	.54	8
THK	.92	.52	9	.97	.73	4	.93	.55	8
ENDU	.58	.11	72	.81	.28	23	.90	.44	12
Fabric Group 2									
FLEX	.95	.61	6	.95	.65	5	.97	.74	4
SURF	.93	.53	8	.96	.66	5	.98	.80	3
WGT	.93	.54	8	.97	.74	4	.95	.63	6
THK	.94	.58	7	.97	.75	4	.96	.69	5
ENDU	.51	.09	96	.66	.15	51	.70	.18	43
Fabric Group 3									
FLEX	.96	.66	5	.97	.77	3	.98	.83	2
SURF	.93	.56	8	.96	.71	4	.92	.52	9
WGT	.98	.80	3	.99	.85	2	.98	.79	3
THK	.96	.66	5	.98	.80	3	.97	.75	3
ENDU	.78	.24	29	.72	.19	38	.85	.34	18

r_{SB} = Spearman Brown reliability coefficient
r_I = intraclass correlation
$J_{.90}$ = number of judges required to give reliability coefficient of .90.

FLEX = Flexibility
SURF = Surface Roughness
WGT = Weight
THK = Thickness
ENDU = End use suitability for men's summer dress slacks

evaluation method. Across the four methods and three fabric groups, the highest number of judges was nine for the rating scale and paired comparison methods while the highest number required for the rank order method was five judges.

5.2.8. Predictive Validity.

In this study predictive validity was determined by the correlation of subjective scale values with the physical measurements of the fabric attributes. Physical properties measured on the Kawabata Evaluation System were the criterion measurements.

The Pearson product-moment correlation coefficients of the flexibility scale values with the physical measurements of bending rigidity and the hysteresis of bending are presented in Table 7.1. The judges were told to measure the degree to which a fabric resisted bending. The physical property related to this definition was the measure of bending rigidity (B). Only the correlations for fabric group 3 were greater than .80 and significantly different from zero. The judges did not evaluate the flexibility of the fabrics in the same manner that the equipment did. The data provides weak evidence for validity of the subjective measurements of flexibility when the criterion is the Kawabata measurement of fabric bending rigidity.

The physical measurement of geometrical roughness (SMD) was the property which measured the divergence of a fabric surface from planeness. The correlations between the objective and subjective measurements of surface roughness are presented in Table 7.2. The correlations with SMD are all lower than .70 and none are significantly different from zero. The judges were not able to evaluate the surface of the fabrics with the same sensitivity that the Kawabata equipment did. Predictive validity for the subjective measurement of surface roughness was not supported by the data.

The correlations between the judges' perceptions of fabric weight and the physical measurements of weight ranged from .78 to .94, and all were statistically significant at the .05 level. The judges were able to perceive differences in the weight of fabrics. Predictive validity was supported by the data, in that the judges were able to measure what they were asked to measure.

The measurement of fabric thickness at .05 grams force (T) was the physical property that was specified as the criterion measurement to correlate with the judges' perceptions of thickness. For fabric groups 1 and 2, the correlations were low with only the correlation of T with the paired comparison evaluation of thickness significantly different from zero at .69. For fabric group 3, T correlated strongly with the judges' perceptions of fabric thickness. This is consistent with the high correlations between all measurements of fabrics in this group. In general, the thickness correlations provide weak evidence that the judges subjectively measure fabric thickness as characterized by the Kawabata Evaluation System.

The analysis of predictive validity also indicates that even when attributes are very specifically defined for a panel of judges, there is no way of assuring that they will evaluate the fabrics in the way specified. When asked to concentrate on one particular property, a person cannot ignore all the other properties of a fabric influence the

Table 7.1. Correlation of Subjective Flexibility Measurements with Physical Measurements of Bending Properties.

KES Property	RSFLEX	ROFLEX	PCFLEX
	Fabric Group 1		
B	.66	.65	.60
HB	.76*	.75*	.68*
	Fabric Group 2		
B	.72*	.66	.61
HB	.39	.28	.36
	Fabric Group 3		
B	.82*	.89*	.82*
HB	.80*	.89*	.81*

RSFLEX: Flexibility evaluated by rating scale method
ROFLEX: Flexibility evaluated by rank order method
PCFLEX: Flexibility evaluated by paired comparison method

B: Bending rigidity ($gf \cdot cm^2/cm$)
HB: Hysteresis of bending moment ($gf \cdot cm/cm$)

Note: * indicates significance at or below .05

Table 7.2. Correlation of Subjective Surface Roughness Measurements with Physical Measurements of Surface Properties.

KES Property	RSSURF	ROSURF	PCSURF
	Fabric Group 1		
MIU	-.56	-.64	-.59
MMD	-.17	.01	-.25
SMD	.22	.36	.14
	Fabric Group 2		
MIU	-.36	-.47	-.38
MMD	.64	.55	.68*
SMD	.57	.59	.61
	Fabric Group 3		
MIU	-.20	-.29	-.19
MMD	.31	.34	.38
SMD	.55	.56	.66

RSSURF: Surface roughness evaluated by rating scale method
ROSURF: Surface Roughness evaluated by rank order method
PCSURF: Surface Roughness evaluated by paired comparison method

MIU: Coefficient of friction (-)
MMD: Mean deviation of MIU (-)
SMD: Geometrical roughness (micron)

Note: * indicates significance at or below .05.

Table 7.3 Correlation of Subjective Weight Measurements with the Physical Measurement of Weight.

KES Property	RSWGT	ROWGT	PCWGT
	Fabric Group 1		
W	.89*	.89*	.92*
	Fabric Group 2		
W	.78*	.81*	.87*
	Fabric Group 3		
W	.90*	.94*	.94*

RSWGT: Fabric weight evaluated by rating scale method
ROWGT: Fabric weight evaluated by rank order method
PCWGT: Fabric weight evaluated by paired comparison method

W: Fabric weight per unit area (mg/cm^2)

Note: * indicates significance at or below .05.

Table 7.4. Correlation of Subjective Thickness Measurements with the Physical Measurements of Thickness.

KES Property	RSTHK	ROTHK	PCTHK
	Fabric Group 3		
T	.30	.08	.32
	Fabric Group 2		
T	.62	.61	.69*
	Fabric Group 3		
T	.87*	.78*	.81*

RSTHK: Fabric thickness evaluated by rating scale method
ROWGT: Fabric thickness evaluated by rank order method
PCWGT: Fabric thickness evaluated by paired comparison method

T: Fabric thickness (mm)

Note: * indicates significance at or below .05

perception of fabric hand.

5.3. Prediction of Fabric Hand Attributes by Physical Properties.

The study of fabric hand is concerned with developing an understanding of how the physical properties of fabrics are perceived and identified through perception and interpretation of a tactile stimulus. One goal is to reach the point where it is possible to measure the hand attributes of fabrics by laboratory instruments. The first steps toward this goal are to measure the properties of fabrics, both subjectively and objectively, and to study the relationship between the measurements. The analysis of the relationship between the two sets of properties increases the understanding of how fabric hand properties are perceived by human judges.

In this study of the hand attributes of polyester/cotton bottom-weight fabrics, it has been determined that the subjective measurements of flexibility and weight were valid measurements. It was also recognized that the perception of fabric hand attributes involves more than just the sensation of one single physical property.

The Kawabata Evaluation System measures six blocks of properties that have been determined to duplicate the modes and magnitudes of fabric deformation during subjective evaluation of hand attributes. These blocks of properties have been defined in Table 2. The relationship between the subjective scores of flexibility and weight and the sixteen Kawabata parameters was determined through regression analysis. It is recognized that there is a high correlation between properties within one block. The stepwise-block procedure outlined by

Kawabata (29) was performed with the Statistical Analysis System (SAS) General Linear Model procedure. The MAXR model building method was used (57). The steps for the blockwise regression analysis applied to flexibility and weight, subjectively measured by the rank order method, are presented in Appendix H.

The correlation coefficients obtained from the regression analysis of flexibility and weight are reported in Tables 8.1. and 8.2. The best one, two, and three variable models are given for each group of fabrics. Because of the problem of over-fitting a model when data is collected on only nine observations, an adjusted R^2 (R_a^2) was calculated and reported. The analyses show that three variables will explain at least 81% of the variability in the subjective perceptions of flexibility and weight.

The analyses also show again the differences in the responses of the judges to the different fabric groups. The order in which the property blocks were added to the models was different for each fabric group, and therefore so also were the variables in the final regression equations. There are no physical properties common to all three fabric groups in the analysis of either flexibility or weight.

The twenty-seven fabrics were selected from a population of polyester/cotton bottom-weight fabrics as represented by a marketed line of fabrics. They were randomly assigned to groups. The group means for the 16 Kawabata properties are statistically equal. The variances are statistically equal for all properties except for thickness (T)—group 3 is lower, coefficient of friction (MIU)—group 2 is high, and mean deviation of MIU (MMD)—group 3 is high.

Table 8.1. Regression Coefficients for Subjective Flexibility.

Fabric Group	Model
Fabric Group 1	BEST 1 variable model, $R_a^2 = .664$
	ROFLEX = 5.577-(31.123)WC
	BEST 2 variable model, $R_a^2 = .765$
	ROFLEX = 14.102-(27.659)LC-(30.648)WC
	BEST 3 variable model, $R_a^2 = .840$
	ROFLEX = 19.637-(26.105)WC-(0.275)WT-(0.223)RT
Fabric Group 2	BEST 1 variable model, $R_a^2 = .757$
	ROFLEX = -21.606+(29.728)LT
	BEST 2 variable model, $R_a^2 = .797$
	ROFLEX = -22.114+(31.940)LT-(0.121)WT
	BEST 3 variable model, $R_a^2 = .813$
	ROFLEX = -27.681+(30.608)LT-(0.118)WT+(0.113)RT
Fabric Group 3	BEST 1 variable model, $R_a^2 = .786$
	ROFLEX = -3.432+(24.038)B
	BEST 2 variable model, $R_a^2 = .937$
	ROFLEX = -4.240+(17.902)B+(0.569)2HG
	BEST 3 variable model, $R_a^2 = .936$
	ROFLEX = -4.434+(17.822)B+(0.337)G+(0.415)2HG

Note: R_a^2 is the adjusted R^2.

Table 8.2. Regression Coefficients for Subjective Weight.

Fabric Group 1	BEST 1 variable model, $R_a^2 = .369$
	ROWGT = 31.891-(44.257)LT
	BEST 2 variable model, $R_a^2 = .852$
	ROWGT = 27.494-(0.498)WT-(0.412)RT
	BEST 3 variable model, $R_a^2 = .898$
	ROWGT = 30.060-(0.474)WT-(0.409)RT-(0.065)RC
Fabric Group 2	BEST 1 variable model, $R_a^2 = .695$
	ROWGT = -15.920+(50.606)LC
	BEST 2 variable model, $R_a^2 = .692$
	ROWGT = -11.456+(38.563)LC-(24.922)MMD
	BEST 3 variable model, $R_a^2 = .827$
	ROWGT = 5.719-(23.381)WC-(112.841)MMD+(0.294)SMD
Fabric Group 3	BEST 1 variable model, $R_a^2 = .888$
	ROWGT = -10.920+(0.532)W
	BEST 2 variable model, $R_a^2 = .888$
	ROWGT = -10.160+(0.436)W+(0.183)2HG5
	BEST 3 variable model, $R_a^2 = .891$
	ROWGT = -6.877-(0.158)T+(0.528)W+(0.224)2HG5

Note: R_a^2 is the adjusted R^2.

The data collected during this study does not indicate what differences between the three groups of fabrics would account for the differences in the regression equations derived from the subjective and objective measurements of hand attributes. The results do show that the regression coefficients derived from a small sample of polyester/cotton bottom-weight fabrics do not predict the attributes of another small group from the same population.

Regression analysis was also used to determine the relationship between the hand attributes of flexibility and weight, and the perceived suitability of the fabrics for use in men' summer dress slacks. The regression coefficients are given in Table 9. Following the work of Kawabata (29), a quadratic model was fit to the data obtained by the rank order scaling method.

The regression model explained 92% of the variability of the judges perception of the suitability of the fabrics in group 1 for men's summer dress slacks. For groups 2 and 3, the model explained 66% and 62% respectively. In order to explain more of the variability for these two groups it will be necessary to determine other attributes that influence the evaluation of fabrics for this specified end use.

Table 9. Regression Coefficients for End Use Suitability.

Fabric Group 1: R_a^2 = .918

$$ROENDU = 0.446-(0.542)ROFLEX+(0.168)ROWGT-(0.231)FLEX^2-(0.024)WGT^2$$

Fabric Group 2: R_a^2 = .664

$$ROENDU = 0.038-(0.442)FLEX-(0.186)WGT+(0.014)FLEX^2-(0.015)WGT^2$$

Fabric Group 3: R_a^2 = .616

$$ROENDU = 0.224-(1.987)FLEX+(1.4957)WGT+(0.316)FLEX^2-(0.432)WGT^2$$

Note: R_a^2 is the adjusted R^2.

6. SUMMARY AND CONCLUSIONS

From this research involving the methods of hand evaluation of polyester/cotton bottom-weight fabrics conclusions can be drawn in the areas of hand terminology, evaluation method validity and reliability, and subjective-objective measurement correlation.

Responses to a hand terminology survey guided the selection of hand attributes that were consistent with those used in the textile industry to describe the hand of polyester/cotton bottom-weight fabrics.

1. Responses showed that fabric flexibility, compressibility, resilience, thickness, weight, density, and surface characteristics influence the subjective evaluation of the hand of polyester/cotton bottom-weight fabrics.

Twenty-seven polyester/cotton bottom-weight fabrics were randomly assigned to three groups. Rating scale, rank order and paired comparison methods were used by eleven expert judges to evaluate the flexibility, surface roughness, weight and thickness of each group of fabrics.

2. Fabrics judged most suitable for use in men's summer dress slacks were most pliable, most smooth, thinnest and lightest in weight.

Multitrait-multimethod matrices were constructed of correlations between the fifteen method-attribute scales obtained through the subjective hand evaluation test procedures. One matrix was constructed for each fabric group. Convergent and discriminant validity, reliability, and method and trait variance of the subjective evaluation procedures were determined by the analysis of these matrices.

3. No difference in validity or reliability was found between the rating scale, rank order and paired comparison evaluation methods.

4. The subjective measurements of flexibility and weight and end use suitability were valid. Surface roughness was equated with flexibility and thickness was equated with fabric weight.

5. For the evaluation of flexibility, surface roughness, weight and thickness, rank order evaluation method required the fewest number of judges to achieve a reliability of .90. In the evaluation of flexibility and weight, the highest number of judges required was five.

6. There is higher variability in the evaluation of fabrics for suitability in men's summer dress slacks, and therefore more judges are required to reach an acceptable reliability. For the evaluation of end use suitability, the paired comparison method was the most efficient.

7. The correlation between subjective measurements of fabric flexibility, surface roughness, thickness and weight differed between the three randomly assigned fabric groups.

The subjective scale values obtained for the fabrics in each group were related to KES measurements fabric properties through regression analysis, with the objective of developing equations that would allow prediction of hand attributes by objective measurements.

8. The correlation between the 16 physical properties of hand evaluated with the Kawabata Evaluation System differed between the

three fabric groups.

9. Translation equations developed from the subjective and objective measurements of fabric hand properties of a small sample randomly selected from a population of polyester/cotton bottom-weight fabrics do not predict the hand attributes of another small sample from the same population.

7. RECOMMENDATIONS FOR FURTHER STUDY.

The terminology survey gave good information concerning the variability in individual interpretations of hand terminology. The next step toward reaching an understanding of the relationship between hand terminology, fabric characteristics and hand evaluation of polyester/cotton bottom-weight fabrics would be a quantitative approach toward eliciting fabric hand terminology from expert judges.

The multitrait-multimethod matrix was a valuable tool in the evaluation of scaling methods and in the analysis of hand attributes. It requires an investment in man-hours and materials to use two or more methods and attributes. However, its use with different methods, different attributes and/or fabric types will give added dimension to the understanding of subjective hand evaluation.

The differences in the responses of both judges and equipment to the three fabric groups indicates that the application of information gained from small sample studies of this type of fabric is limited. It is possible that random selection does not guarantee an adequate distribution of fabric properties for the purpose of developing prediction equations. If specific analysis of properties is used to systematically assign fabrics to experimental groups, an understanding of the magnitude of property differences that are perceived by human judges will be important. Also necessary will be the knowledge of the range of properties in the group from which the fabrics are to be selected.

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APPENDICES

LIST OF APPENDIX TABLES

APPENDIX A. HAND TERMINOLOGY SURVEY

IDENTIFICATION AND DEFINITION OF HAND TERMINOLOGY

The following page contains a list of terms that have been used to describe the hand of fabrics. Please look the list over and circle the words that you use in describing the hand of polyester/cotton bottom-weight fabrics.

The last pages provides space for you to briefly define each term that you have circled and to indicate which of the following properties is most closely related to the term as you use it:

1) Flexibility
2) Compressibility
3) Extensibility
4) Resilience
5) Shearability
6) Density
7) Thickness
8) Weight
9) Surface Contour
10) Surface Friction
11) Moisture Regain
12) Thermal Character
13) Overall Fabric Hand

If there are terms that you use and that are missing from the list, they should also be identified and defined in the spaces provided.

FABRIC HAND DESCRIPTORS

Bitey
Bloom
Boardy
Body
Bounce
Bristly
Bulky

Clammy
Clean
Clingy
Coarse
Close
Cold
Comfortable
Compact
Compliant
Cool
Cottony
Cover
Creasability
Crisp

Damp
Dead
Desirable
Drapeable
Dry

Elastic

Fine
Firm
Fit
Flexible
Flimsy
Foody
Full
Furry
Fuzzy

Gentle
Greasy
Gummy

Hairy
Hard
Harsh
Heavy
Hungry

Kind
Kissed

Lean
Leathery
Light
Limp
Lively
Lofty
Loose
Lumpy

Mellow
Moisture-absorbent
Mushy
Muss-resistant
Mussy

Nappy
Nervous

Oily
Open

Papery
Picky
Pliable
Pucker
Puffy

"Quality"
Quiet

Raspy
Resilient
Rich
Rough
Rubbery
Rustly

Sandy
Scratchy
Scroopy
Sharp
Sheer
Shiny
Silky
Sleazy
Slick

Slippery
Smooth
Snagging
Snap
Soft
Solid
Spongy
Springy

Sticky
Stiff
Stretchy
Style
Supple

Tapery
Thick
Thin
Thready
Tight

Velvety

Warm
Waxy
Weighty
Well-bedded
Wooly
Wrinkling
Wiry

TERM	DEFINITION	PROPERTY

Table A.1. Identified Terms and Definitions

TERM	DEFINITION
Bitey	Unkind touch
Bloom	Fabric is resilient/ Desirable hand
Boardy	Stiff, hardy Stiff hand, crunches like paper, undesirable A stiffness, lack of drape or bending Thick, stiff, no compressibility Stiff, rigid, no drape Hand is stiff, nondesirable Stiff, firm, thick, bulky Stiff, less flexible Stiff, not very flexible Stiff, unbending Very stiff hand, feel of a stiff starched shirt
Body	Firm, heavy hand for its weight Normal hand, average feeling cloth Describes thickness, bulky, full thick Firmness, construction Thickness or fullness; some resilience Overall weight and feel
Bounce	Lively, bounces back after wrinkling, desirable Almost rubber-like recovery Liveliness
Bristly	Raspy; prickly; lack of softness A brush-like surface feel
Bulky	Related to body but fuller and more compressible Heavy, thick Heavy feel Thick, heavy, warm (maybe)
Clammy	Feels like there is something on the surface Unpleasant, moist, cold surface feel Cold, damp
Clean	Excellent appearance, no imperfections
Clingy	Static type clinging to skin Feels like there is something on the surface
Coarse	Undesirable, poor to the touch, not comfortable Rough feel You can feel the firm yarn and fibers

Table A.1. Identified Terms and Definitions, continued.

TERM	DEFINITION
Cottony	Soft, drapy, smooth Soft, smooth No resistance to compression, soft, no bounce, doesn't spring back Soft, natural feel Soft, good quality The feel of cotton
Cover	Levelness of dyeing Density of pile Good opacity (light colors) Overall appearance Lacks cover or has good cover
Creasability	Ability to hold a crease How it creases
Crisp	Stiffness, but not boardy Opposite of bulky, full, etc. Stiff, less flexible Cool, thin, low compressibility, hard surface feel Firm, as in a freshly pressed shirt, sometimes desirable Thin, flat, stiff Thin and stiff
Damp	Feels like there is something on the surface
Dead	Limp, dry Liveliness Opposite of bounce. Poor recovery. Opposite of bounce, stays as you shape it
Drapeable	Flowing/lightweight How it hangs Drapes well Hangs well, follows body, not stiff Very flexible The ability of a fabric to hang in graceful folds Not stiff The way a fabric hangs Flowing, soft, loose

Table A.1. Identified Terms and Definitions, continued.

TERM	DEFINITION
Dry	Has a dry feeling Lack of smoothness, a thinness Opposite of bulky, full, etc. Not soft Unpleasant non-compliant surface feel No surface smoothness, cool feeling
Elastic	Stretch
Firm	Stiffness, but not boardy Stiff, tight Opposite of soft, no drape Bottom wt. oriented "not drapeable" Stiffer than a natural or unfinished fabric Stiff, less flexible
Flimsy	Thin and flexible Related to bulky but softer, more compressible No guts, no "body" Loose, drapy, thin Soft, no body
Full	Bulky, thick Like body Opposite of thin, thickness with body Lofty and thick
Fuzzy	Hairy, soft (usually) Hairy surface Hairy Broken filaments sticking up on the face of fabric
Grainy	Feels like emery cloth
Greasy	Slickness, smooth, slippery Feels like there is something on the surface
Hairy	You can feel the surface nap as individual hairs Hairy Fuzzy, soft (usually a visual description) Too many surface fibers, fuzzy Hairy surface Undesirable (not finished properly

Table A.1. Identified Terms and Definitions, continued.

TERM	DEFINITION
Harsh	Raspy surface Stiff, raspy, firm, unpleasant Unkind touch Has a harsh feel Undesirable, coarse hand Hand rough to touch
Heavy	Firm, heavy hand for its weight, high modulus of compression Heavy, thick
Hungry	Thin, unconstructed Feel yarns, open
Kind	Feels soft and drapeable Not rough, feels like a baby Soft, pleasant, compliant surface Gentle to touch
Lean	Thin, unconstructed
Light	No guts, no "body"
Limp	No guts, no "body" Thin and flexible Soft, no body Soft, thin, lack of body Lack of body
Lively	Resilient, light hand
Lofty	Like body Thick, raised surface Full, thickness
Moisture ab.	How sucks up moisture Amount of water absorbed by a piece of cloth
Mushy	Low modulus of compression, no body Too soft, undesirable
Mussy	Pilly surface Look of fabric Looks mussy, not clean
Nappy	Has a nappy appearance

Table A.1. Identified Terms and Definitions, continued.

TERM	DEFINITION
Oily	Slickness, smooth, slippery Feels like there is something on the surface Greasy, oily surface feel
Open	Amount of construction
Papery	Thin, hard, low compressibility, lack of bulk and fullness Thin, slick Thin, stiff Thin and stiff
Pucker	Visual appearance, bubbly
Quality	No defects
Quiet	Noise of fabric
Raspy	Raspy surface Coarse hand, uncomfortable Harsh, prickly, stiff Unkind touch Feels harsh and raspy Bad dry, talks to you (noisy) Feels wiry Harsh hand Feels like emery cloth
Resilient	Self-explanatory Return to shape Bounces back
Rubbery	High resilience, plastic surface feel, stretch
Rustly	Stiff, loud, raspy (maybe)
Sandy	Feels like emery cloth
Scratchy	Prickly, rough, thin How it feels to touch Feels like emery cloth Coarse and bristly
Scroopy	Noise, feel
Shiny	How it looks High reflectance

Table A.1. Identified Terms and Definitions, continued.

TERM	DEFINITION
Silky	Smooth, drapeable Smooth, drapy, pleasant, light, resilient hand
Sleazy	Thin and flexible Thin, unconstructed No guts, no "body"
Slick	Synthetic hand, undesirable Thin Smooth, greasy, flat Very smooth surface Unpleasant, very plastic surface
Smooth	Round, cool Generally associated with weave and fineness of yarns
Snagging	Fabric would snag or prone to snag when rubbed
Soapy	Soft, moist, cool chamois-like feel
Soft	Cotton-like, good aesthetics Drapeable, light-feeling, smooth No body, unconstructed, too much drape Not stiff or dry Smooth Surface, good drape, easy compressibility Anti-raspy
Spongy	Rubbery, very low modulus of compression, plastic surface feel Bounces back
Springy	Very resilient
Stiff	Stiff, unbending Boardy, firm flat Stiff
Stretchy	How far it extends Stretchy
Supple	Full, round, silky, flowing Soft, some body, good drape, some compressibility, some fullness
Tapery	Describes body

Table A.1. Identified Terms and Definitions, continued.

TERM	DEFINITION
Thick	Heavy feel How much dimension fabric has Full, heavy, body Not thin
Thin	Thin and flexible Describes body Flat, light, papery Does not have enough body Not thick Lightweight places in the fabric
Thready	How many threads, construction you feel
Velvety	Very soft, warm, compliant surface feel
Warm	Fall hand, soft, wool-like Warm to the touch
Waxy	Slickness, smooth, slippery Feels like there is something on the surface
Wooly	Warm, natural feel Scratchy, rough Too much surface hair, rough feel, friction Hairy, fuzzy
Wrinkling	Performance of fabric Creases randomly across fabric, not hard and set, would come out with light pressing

Table A.2. Hand Terminology Related to Fabric Properties.

FLEXIBILITY	COMPRESSIBILITY	RESILIENCE
Boardy (9)	Boardy (3)	Bloom
Creasability	Body	Boardy
Crisp (5)	Bulky (2)	Body
Dead	Cottony	Bounce (3)
Drapeable (6)	Crisp (3)	Bulky
Firm (3)	Drapeable (2)	Cottony
Flimsy (3)	Firm (2)	Creasability
Full	Flimsy	Dead (3)
Heavy	Full (3)	Firm
Kind (2)	Heavy	Flimsy (2)
Light	Kind	Full
Limp (2)	Mushy (2)	Kind
Lively	Open	Limp
Mushy	Papery (3)	Lively
Papery	Raspy	Mussy
Raspy	Resilient	Papery
Rustly	Slick	Resilient (3)
Silky	Soapy	Rubbery
Sleazy (2)	Soft (2)	Silky
Soft (2)	Spongy	Soft (2)
Stiff (2)	Springy	Springy (2)
Supple	Stiff	Supple
Thin	Supple	
Wrinkling	Thin	

DENSITY	THICKNESS	WEIGHT
Body (2)	Boardy	Body (2)
Bulky (3)	Body (2)	Bulky (2)
Cover (2)	Bulky	Cover
Crisp (2)	Crisp	Crisp (2)
Dry	Flimsy	Drapeable
Firm	Full (2)	Dry
Full (2)	Heavy	Firm
Heavy	Hungry	Flimsy (2)
Hungry	Limp	Full
Lean	Lively	Heavy
Lofty (2)	Lofty (2)	Hungry
Shiny	Papery	Limp (2)
Sleazy	Sleazy	Lofty
Soft	Spongy	Sleazy
Tapery	Thick (3)	Soft
Thick	Thin (3)	Tapery
Thin		Thick (2)
		Thin (3)

Table A.2. Hand Terminology Related to Fabric Properties, continued.

SHEARABILITY

- Boardy (2)
- Drapeable (2)
- Kind
- Papery
- Wrinkling

EXTENSIBILITY

- Crisp
- Elastic
- Mushy
- Rubbery
- Spongy
- Stretchy (2)

SURFACE CONTOUR

- Clean
- Coarse
- Cottony
- Cover
- Creasability
- Fuzzy (2)
- Grainy
- Hairy (4)
- Kind
- Pucker
- Raspy (2)
- Rubbery
- Sandy
- Scratchy (2)
- Shiny
- Slick (3)
- Smooth
- Soft
- Velvety
- Wooly (2)

THERMAL CHARACTER

- Clammy (2)
- Kind
- Rubbery
- Silky
- Slick
- Soapy
- Velvety
- Warm (2)

SURFACE FRICTION

- Bitey
- Bristly (2)
- Coarse (3)
- Cottony (3)
- Crisp (2)
- Dry (4)
- Fuzzy (3)
- Greasy (2)
- Gummy
- Hairy (4)
- Harsh (5)
- Kind (3)
- Mussy
- Oily (2)
- Quiet
- Raspy (6)
- Rubbery
- Scratchy (3)
- Scroopy
- Silky (2)
- Slick (2)
- Smooth
- Snagging
- Soapy
- Soft (2)
- Spongy
- Supple
- Thready
- Velvety
- Warm
- Wooly (3)

MOISTURE REGAIN

- Clammy (2)
- Dry (2)
- Kind
- Moisture absorb.(2)
- Silky
- Warm

OVERALL FABRIC HAND

- Boardy (2)
- Body (3)
- Bulky (2)
- Clinging
- Cottony (2)
- Crisp
- Dead
- Dry
- Firm
- Flimsy
- Full (2)
- Hairy
- Harsh
- Heavy
- Hungry
- Kind
- Lean
- Lofty
- Mushy
- Paper
- Raspy
- Rubbery
- Silky
- Sleazy
- Soapy
- Soft (2)
- Spongy
- Supple (2)
- Thick
- Wooly

(#) indicates number of respondents assigning term to that property.

APPENDIX B. PANELIST DEMOGRAPHIC DATA

Demographic Questionnaire

Judge #________

1. Sex________
2. Age________
3. Place of Birth________________________
4. Educational Background (fill in appropriate spaces)
   a. High School: Years completed ________________
   b. College: Years completed ________________
      Major Area of study ________________
      Degree earned ________________
   c. Graduate School: Years completed ________________
      Major area of study ________________
      Degree(s) earned ________________
5. Textile/Apparel Related Experience:

Position Description	Years

Demographic Profile of Judges

		Count	Percent
Sex:	Male	11	100
	Female	0	0
Age:	36-45 years	3	27
	46-55 years	5	45
	56-65 years	3	27
Place of Birth:	United States	10	91
	Other	1	9
Education:	High School	11	100
	College	10	91
	Graduate School	3	27
Textile Experience:	Manufacturing/ Dyeing/Finishing	8	73
	Quality Control/ Customer Service	5	45
	Marketing/Sales	3	27
	Research/Development	7	64

APPENDIX C. SUBJECTIVE HAND EVALUATION DATA

Table C.1.1. Rating Scale Values for Fabric Group 1.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
1	4.273 (0.384)	3.818 (0.400)	4.636 (0.411)	4.545 (0.366)	5.909 (0.610)
2	3.545 (0.247)	3.273 (0.488)	5.364 (0.432)	5.182 (0.444)	4.909 (0.513)
7	3.818 (0.483)	3.091 (0.343)	3.909 (0.315)	4.091 (0.415)	7.091 (0.436)
10	6.455 (0.434)	5.727 (0.428)	5.273 (0.333)	4.273 (0.449)	5.818 (0.644)
16	8.545 (0.207)	8.000 (0.330)	7.727 (0.273)	7.364 (0.310)	3.818 (0.761)
17	6.545 (0.366)	6.182 (0.423)	5.364 (0.310)	4.818 (0.553)	5.636 (0.691)
20	5.091 (0.343)	4.727 (0.557)	6.909 (0.315)	6.636 (0.432)	5.455 (0.623)
23	3.545 (0.511)	4.182 (0.483)	3.636 (0.378)	3.455 (0.434)	5.909 (0.680)
27	2.182 (0.122)	3.000 (0.381)	3.091 (0.251)	3.818 (0.519)	4.818 (0.32)

Note: number in parentheses is the standard error of the mean.

Table C.1.2. Rating Scale Values for Fabric Group 2.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
4	6.182 (0.400)	5.545 (0.390)	4.818 (0.352)	3.818 (0.296)	6.000 (0.447)
9	5.091 (0.343)	3.636 (0.388)	6.545 (0.390)	5.909 (0.392)	5.545 (0.434)
11	7.091 (0.285)	6.000 (0.486)	6.091 (0.436)	5.727 (0.359)	4.818 (0.658)
15	5.727 (0.428)	5.909 (0.456)	3.000 (0.618)	2.636 (0.279)	6.182 (0.711)
18	3.091 (0.211)	2.818 (0.296)	3.818 (0.400)	3.455 (0.455)	6.182 (0.711)
19	3.727 (0.273)	3.091 (0.392)	4.273 (0.273)	4.636 (0.388)	6.000 (0.539)
21	5.182 (0.615)	4.000 (0.405)	3.545 (0.207)	4.182 (0.325)	5.636 (0.472)
22	5.091 (0.495)	3.636 (0.338)	4.818 (0.263)	4.636 (0.338)	5.364 (0.472)
24	7.454 (0.282)	5.182 (0.519)	6.818 (0.400)	6.727 (0.407)	3.727 (0.524)

Note: number in parentheses is the standard error of the mean.

Table C.1.3. Rating Scale Values for Fabric Group 3.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
3	6.454 (0.545)	6.818 (0.377)	7.091 (0.343)	6.636 (0.472)	4.636 (0.664)
5	6.091 (0.578)	6.364 (0.432)	7.455 (0.366)	6.818 (0.325)	3.909 (0.639)
6	7.273 (0.359)	5.909 (0.343)	7.182 (0.263)	6.818 (0.501)	3.545 (0.608)
12	3.727 (0.359)	3.545 (0.511)	3.273 (0.273)	3.364 (0.310)	6.455 (0.455)
13	2.909 (0.163)	3.727 (0.359)	3.364 (0.310)	2.545 (0.340)	6.727 (0.604)
14	4.455 (0.312)	5.000 (0.405)	4.364 (0.338)	5.091 (0.285)	6.818 (0.296)
25	6.000 (0.270)	6.364 (0.364)	6.364 (0.279)	6.091 (0.436)	4.364 (0.560)
26	3.455 (0.366)	4.000 (0.234)	3.545 (0.282)	3.364 (0.338)	6.273 (0.604)
28	2.273 (0.333)	3.091 (0.547)	2.182 (0.226)	2.727 (0.634)	5.727 (0.832)

Note: number in parentheses is the standard error of the mean.

Table C.2.1. Rank Order Scale Values for Fabric Group 1.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
1	4.545 (0.312)	5.000 (0.330)	4.182 (0.377)	4.000 (0.302)	6.636 (0.432)
2	2.909 (0.595)	2.818 (0.352)	6.182 (0.483)	5.818 (0.483)	6.182 (0.600)
7	3.545 (0.390)	2.545 (0.390)	3.273 (0.524)	4.273 (0.407)	5.909 (0.368)
10	7.091 (0.285)	7.091 (0.163)	5.273 (0.488)	5.182 (0.615)	4.455 (0.652)
16	9.000 (0.000)	9.000 (0.000)	8.818 (0.122)	8.636 (0.244)	1.545 (0.455)
17	7.182 (0.226)	6.909 (0.625)	5.636 (0.453)	5.636 (0.592)	3.818 (0.736)
20	5.818 (0.444)	4.455 (0.593)	7.636 (0.310)	7.818 (0.182)	5.727 (0.843)
23	3.545 (0.493)	4.455 (0.623)	1.727 (0.304)	1.818 (0.444)	5.273 (0.787)
27	1.364 (0.203)	2.091 (0.368)	2.091 (0.392)	1.818 (0.296)	5.273 (0.905)

Note: number in parentheses is the standard error of the mean.

Table C.2.2. Rank Order Scale Values for Fabric Group 2.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
4	6.000 (0.522)	6.182 (0.263)	3.727 (0.384)	3.636 (0.432)	4.818 (0.761)
9	3.818 (0.644)	3.636 (0.650)	7.455 (0.390)	7.909 (0.251)	5.182 (0.932)
11	7.818 (0.483)	8.273 (0.273)	7.636 (0.544)	7.182 (0.423)	4.182 (0.923)
15	6.273 (0.574)	7.818 (0.444)	1.091 (0.091)	1.455 (0.207)	5.091 (0.719)
18	1.364 (0.152)	1.818 (0.325)	2.727 (0.237)	3.182 (0.464)	7.000 (0.647)
19	2.545 (0.366)	3.364 (0.364)	6.273 (0.428)	5.636 (0.388)	6.000 (0.688)
21	4.364 (0.560)	4.545 (0.594)	3.364 (0.411)	2.818 (0.296)	5.545 (0.666)
22	4.727 (0.304)	2.727 (0.359)	5.091 (0.495)	4.727 (0.506)	5.364 (0.544)
24	7.909 (0.251)	6.727 (0.467)	7.636 (0.338)	8.455 (0.207)	2.455 (0.593)

Note: number in parentheses is the standard error of the mean.

Table C.2.3. Rank Order Scale Values for Fabric Group 3.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
3	6.727 (0.273)	8.273 (0.273)	6.636 (0.453)	7.000 (0.270)	4.091 (0.814)
5	7.727 (0.273)	6.727 (0.333)	8.455 (0.207)	8.364 (0.310)	3.636 (0.717)
6	8.182 (0.553)	7.545 (0.247)	8.182 (0.226)	7.818 (0.296)	3.273 (0.727)
12	3.091 (0.456)	3.273 (0.333)	3.091 (0.285)	2.909 (0.285)	6.727 (0.619)
13	2.545 (0.312)	3.182 (0.464)	2.364 (0.364)	2.455 (0.247)	6.818 (0.585)
14	4.273 (0.304)	3.818 (0.444)	4.818 (0.263)	4.818 (0.122)	6.364 (0.411)
25	6.909 (0.285)	6.909 (0.530)	6.182 (0.263)	6.545 (0.455)	3.455 (0.638)
26	3.727 (0.359)	3.364 (0.411)	3.727 (0.195)	3.727 (0.428)	5.818 (0.569)
28	1.455 (0.207)	1.636 (0.388)	1.182 (0.122)	1.364 (0.244)	4.182 (0.989)

Note: number in parentheses is the standard error of the mean.

Table C.3.1.1.a. Flexibility Preference Matrix of Cell Counts for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	/	3	5	10	11	11	9	2	0
2	8	/	7	11	11	10	11	6	2
7	6	4	/	10	11	11	9	6	1
10	1	0	1	/	10	2	2	0	0
16	0	0	0	1	/	1	1	0	0
17	0	1	0	9	10	/	4	0	1
20	2	0	2	9	10	7	/	1	0
23	9	5	5	11	11	11	10	/	2
27	11	9	10	11	11	10	11	9	/

Table C.3.1.1.b. Flexibility Preference Matrix of Proportions for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	0.500	0.273	0.455	0.909	1.000	1.000	0.818	0.181	0.000
2	0.727	0.500	0.636	1.000	1.000	0.909	1.000	0.545	0.182
7	0.545	0.364	0.500	0.909	1.000	1.000	0.818	0.545	0.091
10	0.091	0.000	0.091	0.500	0.909	0.182	0.182	0.000	0.000
16	0.000	0.000	0.000	0.091	0.500	0.091	0.091	0.000	0.000
17	0.000	0.091	0.000	0.818	0.909	0.500	0.364	0.000	0.091
20	0.182	0.000	0.182	0.818	0.909	0.636	0.500	0.091	0.000
23	0.818	0.455	0.455	1.000	1.000	1.000	0.909	0.500	0.181
27	1.000	0.818	0.909	1.000	1.000	0.909	1.000	0.818	0.500

Table C.3.1.1. Flexibility Preference Matrix of Normal Deviates for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	0.000	−0.605	−0.114	1.335	4.265	4.265	0.909	−0.909	−4.265
2	0.605	0.000	0.349	4.265	4.265	1.335	4.265	0.114	−0.909
7	0.114	−0.349	0.000	1.335	4.265	4.265	0.909	0.114	−1.335
10	−1.335	−4.265	−1.335	0.000	1.335	−0.909	−0.909	−4.265	−4.265
16	−4.265	−4.265	−4.265	−1.335	0.000	−1.335	−1.335	−4.265	−4.265
17	−4.265	−1.335	−4.265	0.909	1.335	0.000	−0.349	−4.265	−1.335
20	−0.909	−4.265	−0.909	0.909	1.335	0.349	0.000	−1.335	−4.265
23	0.909	−0.114	−0.114	4.265	4.265	4.265	1.335	0.000	−0.909
27	4.265	0.909	1.335	4.265	4.265	1.335	4.265	0.909	0.000
Sum	− 4.881	−14.309	− 9.318	15.948	25.330	13.570	9.090	13.902	21.548
Average	− 0.542	− 1.588	− 1.035	1.772	2.814	1.508	1.010	− 1.545	− 2.394
Final Scale	3.249	2.203	2.756	5.563	6.605	5.299	4.801	2.246	1.379

Table C.3.1.2. Flexibility Preference Matrix of Normal Deviates for Fabric Group 2.

Fabric	4	9	11	15	18	19	21	22	24
4	0.000	-0.605	0.605	-0.349	-4.265	-1.335	-0.909	-1.335	-0.114
9	0.605	0.000	1.335	1.335	-1.335	-0.909	0.114	-0.114	4.265
11	-0.605	-1.335	0.000	-0.909	-4.265	-4.265	-4.265	-4.265	-0.605
15	0.349	-1.335	0.909	0.000	-4.265	-1.335	-1.335	-0.349	0.349
18	4.265	1.335	4.265	4.265	0.000	1.335	4.265	1.335	4.265
19	1.335	0.909	4.265	1.335	-1.335	0.000	0.349	0.114	4.265
21	0.909	-0.114	4.265	1.335	-4.265	-0.349	0.000	0.114	4.265
22	1.335	0.114	4.265	0.349	-1.335	-0.114	-0.114	0.000	0.909
24	0.114	-4.265	0.605	-0.349	-4.265	-4.265	-4.265	-0.909	0.000
Sum	8.307	- 5.296	20.514	7.012	-25.330	-11.237	- 6.160	- 5.409	17.599
Average	0.923	- 0.589	2.279	0.779	- 2.814	- 1.249	- 0.684	- 0.601	1.955
Final Scale	4.714	3.202	6.070	4.570	0.977	2.542	3.107	3.190	5.746

Table C.3.1.3. Flexibility Preference Matrix of Normal Deviates for Fabric Group 3.

Fabric	3	5	6	12	13	14	25	26	27
3	0.000	0.605	1.335	-4.265	-4.265	-1.335	-0.605	-4.265	-4.265
5	-0.605	0.000	1.335	-4.265	-1.335	-0.909	-0.605	-4.265	-4.265
6	-1.335	-1.335	0.000	-4.265	-4.265	-4.265	-0.605	-4.265	-1.335
12	4.265	4.265	4.265	0.000	-1.335	0.349	4.265	-0.114	-1.335
13	4.265	1.335	4.265	1.335	0.000	0.605	4.265	0.605	-1.335
14	1.335	0.909	4.265	-0.349	-0.605	0.000	4.265	-1.335	-4.265
25	0.605	0.605	0.605	-4.265	-4.265	-4.265	0.000	-4.265	-1.335
26	4.265	4.265	4.265	0.114	-0.605	1.335	4.265	0.000	-4.265
28	4.265	4.265	1.335	1.335	1.335	4.265	1.335	4.265	0.000
Sum	17.060	14.914	21.670	-14.625	-15.341	- 4.220	16.580	-13.639	-22.400
Average	1.896	1.657	2.408	- 1.625	- 1.704	- 0.469	1.842	- 1.516	- 2.489
Final Scale	5.687	5.448	6.199	2.166	2.087	3.322	5.6337	2.275	1.302

Table C.3.2.1. Surface Roughness Preference Matrix of Normal Deviates for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	0.000	0.114	−1.335	4.265	4.265	4.265	0.349	0.114	−0.114
2	−0.114	0.000	−0.605	0.909	4.265	4.265	0.909	0.349	0.349
7	1.335	0.605	0.000	4.265	4.265	4.265	0.909	4.265	0.114
10	−4.265	−0.909	−4.265	0.000	4.265	0.349	−0.909	−4.265	−4.265
16	−4.265	−4.265	−4.265	−4.265	0.000	−4.265	−4.265	−4.265	−4.265
17	−4.265	−4.265	−4.265	−0.349	4.265	0.000	−1.335	−1.335	−1.335
20	−0.349	−0.909	−0.909	0.909	4.265	1.335	0.000	0.605	−1.335
23	−0.114	−0.349	−4.265	4.265	4.265	1.335	−0.605	0.000	−4.265
27	0.114	−0.3489	−0.114	4.265	4.265	1.335	1.335	4.265	0.000
Sum	−11.923	−10.327	−20.023	14.264	34.120	12.884	− 3.612	− 0.267	−15.116
Average	− 1.325	− 1.147	− 2.225	1.585	3.791	1.432	− 0.401	− 0.030	− 1.680
Final Scale	2.466	2.644	1.566	5.376	7.582	5.223	3.391	3.761	2.111

Table C.3.2.2. Surface Roughness Preference Matrix of Normal Deviates for Fabric Group 2.

Fabric	4	9	11	15	18	19	21	22	24
4	0.000	−1.335	0.909	1.335	−4.265	−4.265	−4.265	−0.909	−0.114
9	1.335	0.000	4.265	4.265	−1.335	−0.114	−0.114	−0.114	1.335
11	−0.909	−4.265	0.000	0.605	−4.265	−4.265	−1.335	−4.265	−1.335
15	−1.335	−4.265	−0.605	0.000	−4.265	−4.265	−4.265	−4.265	−0.909
18	4.265	1.335	4.265	4.265	0.000	0.605	4.265	1.335	4.265
19	4.265	0.114	4.265	4.265	−0.605	0.000	0.114	−0.605	4.265
21	4.265	0.114	1.335	4.265	−4.265	−0.114	0.000	−0.349	0.909
22	0.909	0.114	4.265	4.265	−1.335	0.605	0.349	0.000	1.335
24	0.114	−1.335	1.335	0.909	−4.265	−4.265	−0.909	−1.335	0.000
Sum	12.909	− 9.523	20.034	24.174	−24.600	−16.078	− 6.160	−10.507	9.751
Average	1.434	− 1.058	2.226	2.686	− 2.733	− 1.787	− 0.684	− 1.167	1.083
Final Scale	5.225	2.733	6.017	6.477	1.058	2.004	3.107	2.624	4.874

Table C.3.2.3. Surfce Roughness Preference Matrix of Normal Deviates for Fabric Group 3.

Fabric	3	5	6	12	13	14	25	26	28
3	0.000	-0.909	-0.349	-1.335	-1.335	-1.335	-1.335	-1.335	-1.335
5	0.909	0.000	0.349	-0.909	-1.335	-0.114	1.335	-0.909	-1.335
6	0.349	-0.349	0.000	-1.335	-1.335	-0.909	-0.349	-0.909	-1.335
12	1.335	0.909	1.335	0.000	0.114	0.909	1.335	-0.114	-0.909
13	1.335	1.335	1.335	-0.114	0.000	0.909	1.335	0.114	-0.605
14	1.335	0.114	0.909	-0.909	-0.909	0.000	1.335	0.114	-1.335
25	1.335	-1.335	0.349	-1.335	-1.335	-1.335	0.000	-1.335	-1.335
26	1.335	0.909	0.909	0.114	-0.114	-0.114	1.335	0.000	-0.909
28	1.335	1.335	1.335	0.909	0.605	1.335	1.335	0.909	0.000
Sum	9.268	2.009	6.172	- 4.914	- 5.644	- 0.654	6.326	- 3.465	- 9.098
Average	1.030	0.223	0.686	- 0.546	- 0.627	- 0.073	0.703	- 0.385	- 1.011
Final Scale	4.821	4.014	41.477	3.245	3.164	3.718	4.494	4.406	2.780

Table C.3.3.1. Weight Preference Matrix of Normal Deviates for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	0.000	0.909	0.114	0.349	4.265	0.349	1.335	−0.114	−0.605
2	−0.909	0.000	−0.114	−0.349	0.605	−.0349	1.335	−1.335	−0.909
7	−0.114	0.114	0.000	0.605	4.265	0.349	4.265	−0.114	−0.349
10	−0.349	0.349	−0.605	0.000	4.265	0.349	0.909	−4.265	−0.349
16	−4.265	−0.605	−4.265	−4.265	0.000	−1.335	−0.114	−1.335	−1.335
17	−0.349	0.349	−0.349	0.349	1.335	0.000	1.335	−0.605	−0.605
20	−1.335	−1.335	−4.265	−0.909	0.114	−1.335	0.000	−1.335	−4.265
23	0.114	1.335	0.114	4.265	1.335	0.605	1.335	0.000	−0.114
27	0.605	0.909	0.349	0.349	1.335	0.605	4.265	0.114	0.000
Sum	− 6.602	2.025	− 9.021	0.394	17.519	− 1.460	14.665	− 8.989	− 8.531
Average	− 0.734	0.225	− 1.002	0.044	1.947	− 0.162	1.629	− 0.999	− 0.948
Final Scale	3.057	4.016	2.789	3.835	5.738	3.629	5.420	2.792	2.843

Table C.3.3.2. Weight Preference Matrix of Normal Deviates for Fabric Group 2.

Fabric	4	9	11	15	18	19	21	22	24
4	0.000	0.909	1.335	-0.909	-0.349	0.605	-0.349	0.605	4.265
9	-0.909	0.000	0.349	-4.265	-0.349	-1.335	-4.265	-0.605	0.349
11	-1.335	-0.349	0.000	-4.265	-1.335	-0.605	-0.909	-0.349	-0.349
15	0.909	4.265	4.265	0.000	1.335	1.335	0.909	4.265	4.265
18	0.349	0.349	1.335	-1.335	0.000	0.909	-0.349	0.605	1.335
19	-0.605	1.335	0.605	-1.335	-0.909	0.000	-0.605	-0.114	0.909
21	0.349	4.265	0.909	-0.909	0.349	0.605	0.000	4.265	4.265
22	-0.605	0.605	0.349	-4.265	-0.605	0.114	-4.265	0.000	0.114
24	-4.265	-0.349	0.349	-4.265	-1.335	-0.909	-4.265	-0.114	0.000
Sum	- 6.113	11.030	9.496	21.548	- 3.198	0.719	-14.098	8.558	15.153
Average	- 0.679	1.226	1.055	- 2.394	- 0.355	0.080	- 1.566	0.951	1.684
Final Scale	3.112	5.107	4.846	1.397	3.436	3.871	2.2259	4.742	5.475

Table C.3.3.3. Weight Preference Matrix of Normal Deviates for Fabric Group 3.

Fabric	3	5	6	12	13	14	25	26	28
3	0.000	0.909	0.605	-4.265	-4.265	-1.335	-0.605	-4.265	-4.265
5	-0.909	-0.000	0.349	-1.335	-4.265	-1.335	-0.605	-1.335	-4.265
6	-0.605	-0.349	0.000	-4.265	-4.265	-1.335	-1.335	-0.909	-4.265
12	4.265	1.335	4.265	0.000	-0.909	0.909	1.335	0.605	-0.605
13	4.265	4.265	4.265	0.909	0.000	0.909	4.265	0.349	-0.909
14	1.335	1.335	1.335	-0.909	-0.909	0.000	0.909	-0.114	-1.335
25	0.605	0.605	1.335	-1.335	-4.265	-0.909	0.000	-0.909	-4.265
26	4.265	1.335	0.909	-0.605	-0.349	0.114	0.909	0.000	-1.335
28	4.265	4.265	4.265	0.605	0.909	1.335	4.265	1.335	0.000
Sum	17.486	13.700	17.328	-11.200	-18.318	- 1.649	9.138	- 5.243	-21.244
Average	1.943	1.522	1.925	- 1.245	- 2.035	- 0.183	1.015	- 0.583	- 2.360
Final Scale	5.734	5.313	5.716	2.546	1.756	3.608	4.806	3.208	1.431

Table C.3.4.1. Thickness Preference Matrix of Normal Deviates for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	0.000	0.605	0.605	0.605	1.335	0.349	4.265	−0.349	−0.349
2	−0.605	0.000	−1.335	−0.349	0.909	−.0349	1.335	−0.605	−4.265
7	−0.605	1.335	0.000	0.349	0.909	0.114	1.335	−0.605	−0.605
10	−0.605	0.349	−0.349	0.000	1.335	−0.114	0.349	−0.605	−0.349
16	−1.335	−0.909	−0.909	−1.335	0.000	−4.265	−0.349	−0.909	−4.265
17	−0.349	0.349	−0.114	0.114	4.265	0.000	0.909	−0.605	−0.114
20	−4.265	−1.335	−1.335	−0.349	0.349	−0.909	0.000	−1.335	−4.265
23	0.349	0.605	0.605	0.605	0.909	0.605	1.335	0.000	−0.349
27	0.349	4.265	0.605	0.349	4.265	0.114	4.265	0.349	0.000
Sum	− 7.066	5.264	− 2.227	− 0.011	14.276	− 4.455	13.444	− 4.664	−14.561
Average	− 0.785	0.584	− 0.248	− 0.001	1.586	− 0.495	1.494	− 0.518	− 1.618
Final Scale	3.006	4.375	3.543	3.790	5.377	3.296	4.285	3.273	2.173

Table C.3.4.2. Thickness Preference Matrix of Normal Deviates for Fabric Group 2.

Fabric	4	9	11	15	18	19	21	22	24
4	0.000	0.909	4.265	−0.909	−0.114	0.909	−0.114	0.909	4.265
9	−0.909	0.000	0.114	−4.265	−4.265	−0.349	−1.335	−0.909	0.605
11	−4.265	−0.114	0.000	−4.265	−4.265	−1.335	−1.335	−0.909	−0.114
15	0.909	4.265	4.265	0.000	0.909	1.335	1.335	4.265	4.265
18	0.114	4.265	4.265	−0.909	0.000	0.349	0.605	0.605	1.335
19	−0.909	0.349	1.335	−1.335	−0.349	0.000	−0.909	0.605	0.909
21	0.114	1.335	1.335	−1.335	−0.605	0.909	0.000	−0.349	0.909
22	−0.909	0.909	0.909	−4.265	−0.605	−0.605	0.349	0.000	1.335
24	−4.265	−0.605	0.114	−4.265	−1.335	−0.909	−0.909	−1.335	0.000
Sum	−10.120	11.313	16.602	−21.548	−10.629	0.304	− 2.313	2.882	13.509
Average	− 1.124	1.257	1.845	− 2.394	− 1.181	0.034	− 0.257	0.320	1.501
Final Scale	2.667	5.048	5.636	1.397	2.610	3.825	3.534	4.111	5.292

Table C.3.4.3. Thickness Preference Matrix of Normal Deviates for Fabric Group 3.

Fabric	3	5	6	12	13	14	25	26	28
3	0.000	0.605	0.909	-4.265	-4.265	-0.909	-0.114	-1.335	-4.265
5	-0.605	0.000	0.349	-4.265	-1.335	-4.265	-1.335	-4.265	-4.265
6	-0.909	-0.349	0.000	-4.265	-4.265	-0.909	-0.605	-4.265	-4.265
12	4.265	4.265	4.265	0.000	-0.605	1.335	1.335	0.349	-0.909
13	4.265	1.335	4.265	0.605	0.000	1.335	0.909	1.335	-0.605
14	0.909	4.265	0.909	-1.335	-1.335	0.000	0.349	-0.909	-1.335
25	0.114	1.335	0.605	-1.335	-0.909	-0.349	0.000	-0.909	-1.335
26	1.335	4.265	4.265	-0.349	-1.335	0.909	0.909	0.000	-0.909
28	4.265	4.265	4.265	0.909	0.605	1.335	1.335	0.909	0.000
Sum	13.639	19.986	19.832	-14.300	-13.444	- 1.518	2.783	- 9.090	-17.888
Average	1.512	2.221	2.203	- 1.589	- 1.494	- 0.169	0.309	- 1.009	- 1.987
Final Scale	5.303	6.012	5.994	2.202	2.297	3.622	4.100	2.782	1.804

Table C.3.5.1. End Use Preference Matrix of Normal Deviates for Fabric Group 1.

Fabric	1	2	7	10	16	17	20	23	27
1	0.000	-0.114	-0.114	-1.335	-4.265	-0.605	-0.909	0.114	-0.114
2	0.114	0.000	0.605	-0.114	-1.335	-0.114	-0.909	0.114	0.605
7	0.114	-0.605	0.000	-0.605	-4.265	-0.909	-1.335	0.114	0.114
10	1.334	0.114	0.605	0.000	-1.335	-0.349	0.349	1.335	0.114
16	4.265	1.335	4.265	1.335	0.000	4.265	1.335	4.265	1.335
17	0.605	0.114	0.909	0.349	-4.265	0.000	-0.349	0.349	0.114
20	0.909	0.909	1.335	-0.349	-4.335	0.349	0.000	0.605	0.605
23	-0.114	-0.114	-0.114	-1.335	-4.265	-0.349	-0.605	0.000	-0.349
27	0.114	-0.605	-0.114	-0.114	-1.335	-0.114	-0.605	0.349	0.000
Sum	7.342	1.034	7.377	- 2.168	-22.400	2.174	- 3.028	7.245	2.424
Average	0.816	0.115	0.820	- 0.241	- 2.489	0.242	- 0.336	0.805	0.269
Final Scale	4.607	3.906	4.611	3.550	1.302	4.033	3.455	4.596	4.060

Table C.3.5.2. End Use Preference Matrix of Normal Deviates for Fabric Group 2.

Fabric	4	9	11	15	18	19	21	22	24
4	0.000	-0.114	-0.605	0.349	0.909	0.114	0.605	0.349	-0.909
9	0.114	0.000	0.114	0.605	0.605	-0.114	0.114	0.114	-0.349
11	0.605	-0.114	0.000	0.605	0.349	0.909	1.335	1.335	-0.605
15	-0.349	-0.605	-0.605	0.000	0.349	-0.114	0.114	-0.349	-1.335
18	-0.909	-0.605	-0.349	-0.349	0.000	-0.114	-0.349	-1.335	-0.605
19	-0.114	0.114	-0.909	0.114	0.114	0.000	-0.114	-0.114	-0.605
21	-0.605	-0.114	-1.335	-0.114	0.349	0.114	0.000	-0.349	-0.349
22	-0.349	-0.114	-1.335	0.349	1.335	0.114	0.349	0.000	-1.335
24	0.909	0.349	0.605	1.335	0.605	0.605	0.349	1.335	0.000
Sum	- 0.698	- 1.203	- 4.419	2.894	4.615	1.514	2.403	0.986	- 6.092
Average	- 0.078	- 0.134	- 0.491	0.322	0.513	0.168	0.267	0.110	- 0.677
Final Scale	3.713	3.657	3.300	4.113	4.304	3.959	4.058	3.901	3.114

Table C.3.5.3. End Use Preference Matrix of Normal Deviates for Fabric Group 3.

Fabric	3	5	6	12	13	14	25	26	28
3	0.000	0.114	−0.349	0.909	0.909	1.335	−0.114	0.909	0.349
5	−0.114	0.000	−0.349	0.909	0.909	1.335	0.605	1.335	0.605
6	0.349	0.349	0.000	0.909	0.909	0.909	0.114	0.605	0.349
12	−0.909	−0.909	−0.909	0.000	−0.349	−0.349	−1.335	−0.909	−0.909
13	−0.909	−0.909	−0.909	0.349	0.000	−0.349	−0.909	−0.605	−0.605
14	−1.335	−1.335	−0.909	0.349	0.349	0.000	−0.909	0.114	−0.349
25	0.114	−0.605	−0.114	1.335	0.909	0.909	0.000	0.909	0.909
26	0.909	−1.335	−0.605	0.909	0.605	−0.114	−0.909	0.000	−0.605
28	−0.349	−0.605	−0.349	0.909	0.605	0.349	−0.909	0.605	0.000
Sum	− 4.062	− 5.235	− 4.493	6.578	4.846	4.025	− 4.366	2.963	− 0.256
Average	− 0.451	− 0.582	− 0.499	0.731	0.538	0.447	− 0.485	0.329	− 0.028
Final Scale	3.340	3.209	3.292	4.522	4.329	4.238	3.306	4.120	3.763

Table C.4.1. Paired Comparison Scale Values for Fabric Group 1.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
1	4.070 (0.118)	3.887 (0.120)	3.848 (0.155)	3.784 (0.167)	4.770 (0.157)
2	3.623 (0.133)	3.764 (0.116)	4.517 (0.204)	4.537 (0.132)	4.353 (0.143)
7	3.892 (0.081)	3.201 (0.142)	3.885 (0.158)	4.070 (0.142)	4.770 (0.152)
10	5.105 (0.127)	4.867 (0.066)	4.319 (0.116)	4.291 (0.127)	4.069 (0.231)
16	5.688 (0.088)	5.858 (0.000)	5.338 (0.152)	5.372 (0.205)	2.854 (0.122)
17	4.777 (0.064)	5.005 (0.085)	4.125 (0.195)	4.069 (0.169)	4.221 (0.244)
20	4.643 (0.153)	4.197 (0.125)	5.272 (0.132)	5.119 (0.135)	3.931 (0.179)
23	3.670 (0.153)	4.265 (0.096)	3.558 (0.194)	3.763 (0.135)	4.783 (0.181)
27	3.016 (0.099)	3.565 (0.120)	3.605 (0.166)	3.525 (0.165)	4.591 (0.231)

Note: number in parentheses is the standard error of the mean.

Table C.4.2. Paired Comparison Scale Values for Fabric Group 2.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
4	4.880 (0.169)	4.322 (0.100)	3.922 (0.155)	3.756 (0.184)	4.175 (0.158)
9	4.016 (0.127)	3.877 (0.120)	3.712 (0.090)	3.644 (0.150)	4.117 (0.163)
11	5.391 (0.120)	5.227 (0.089)	5.068 (0.203)	5.235 (0.167)	3.817 (0.245)
15	4.691 (0.185)	5.568 (0.134)	2.968 (0.129)	2.968 (0.129)	4.611 (0.288)
18	2.843 (0.088)	2.956 (0.099)	3.891 (0.196)	3.733 (0.114)	4.873 (0.266)
19	3.680 (0.108)	3.766 (0.103)	4.355 (0.112)	4.299 (0.144)	4.463 (0.231)
21	3.942 (0.089)	3.931 (0.123)	3.619 (0.136)	4.044 (0.117)	4.522 (0.173)
22	3.999 (0.101)	3.704 (0.153)	4.574 (0.132)	4.228 (0.108)	4.334 (0.143)
24	5.005 (0.165)	4.676 (0.107)	5.033 (0.159)	5.153 (0.133)	3.548 (0.186)

Note: number in parentheses is the standard error of the mean.

Table C.4.3. Paired Comparison Scale Values for Fabric Group 3.

Fabric	FLEXIBILITY	SURFACE	WEIGHT	THICKNESS	END USE
3	4.903 (0.122)	5.364 (0.210)	4.924 (0.108)	4.821 (0.138)	3.785 (0.202)
5	4.970 (0.083)	4.449 (0.167)	5.175 (0.151)	5.243 (0.105)	3.675 (0.277)
6	5.568 (0.134)	4.922 (0.158)	5.338 (0.152)	5.329 (0.142)	3.732 (0.199)
12	3.884 (0.102)	3.796 (0.134)	3.723 (0.071)	3.682 (0.094)	5.033 (0.178)
13	3.485 (0.145)	3.729 (0.142)	3.437 (0.148)	3.432 (0.119)	4.803 (0.129)
14	4.134 (0.071)	4.209 (0.094)	4.134 (0.060)	4.353 (0.045)	4.653 (0.040)
25	4.777 (0.064)	4.850 (0.237)	4.612 (0.074)	4.568 (0.157)	3.826 (0.165)
26	4.790 (0.093)	4.931 (0.128)	4.042 (0.095)	3.914 (0.092)	4.571 (0.160)
28	2.848 (0.127)	3.167 (0.290)	2.996 (0.146)	3.065 (0.166)	4.233 (0.253)

Note: number in parentheses is the standard error of the mean.

APPENDIX D. OBJECTIVE HAND EVALUATION DATA.

Table D.1.1. Bending Properties of Fabric Group 1.

Fabric	B1	B2	B	2HB1	2HB2	2HB
1	0.129 (0.002)	0.087 (0.005)	0.108 (0.004)	0.087 (0.011)	0.091 (0.002)	0.089 (0.005)
2	0.146 (0.004)	0.123 (0.001)	0.135 (0.002)	0.116 (0.008)	0.126 (0.007)	0.121 (0.007)
7	0.133 (0.002)	0.074 (0.005)	0.104 (0.003)	0.148 (0.012)	0.083 (0.007)	0.115 (0.009)
10	0.276 (0.004)	0.153 (0.002)	0.215 (0.003)	0.184 (0.003)	0.098 (0.007)	0.141 (0.002)
16	0.323 (0.014)	0.234 (0.007)	0.279 (0.010)	0.425 (0.021)	0.230 (0.010)	0.328 (0.015)
17	0.198 (0.004)	0.132 (0.006)	0.165 (0.005)	0.148 (0.008)	0.098 (0.008)	0.123 (0.006)
20	0.200 (0.003)	0.145 (0.003)	0.173 (0.002)	0.204 (0.015)	0.126 (0.002)	0.165 (0.006)
23	0.360 (0.042)	0.089 (0.009)	0.224 (0.026)	0.226 (0.018)	0.034 (0.005)	0.130 (0.010)
27	0.187 (0.014)	0.113 (0.007)	0.150 (0.009)	0.111 (0.003)	0.105 (0.004)	0.108 (0.003)
Average	0.217 (0.028)	0.128 (0.016)	0.172 (0.019)	0.183 (0.034)	0.110 (0.017)	0.147 (0.024)

Note: number in parentheses is the standard error of the mean.

Table D.1.2. Bending Properties of Fabric Group 2.

Fabric	B1	B2	B	2HB1	2HB2	2HB
4	0.169 (0.018)	0.122 (0.010)	0.146 (0.019)	0.164 (0.021)	0.091 (0.012)	0.128 (0.015)
9	0.212 (0.008)	0.129 (0.005)	0.171 (0.007)	0.298 (0.022)	0.158 (0.011)	0.228 (0.016)
11	0.354 (0.007)	0.253 (0.006)	0.304 (0.010)	0.253 (0.002)	0.164 (0.004)	0.209 (0.009)
15	0.103 (0.004)	0.111 (0.006)	0.107 (0.005)	0.075 (0.004)	0.110 (0.009)	0.092 (0.006)
18	0.150 (0.001)	0.063 (0.004)	0.107 (0.002)	0.150 (0.003)	0.058 (0.003)	0.104 (0.002)
19	0.142 (0.005)	0.108 (0.003)	0.125 (0.001)	0.158 (0.004)	0.102 (0.001)	0.130 (0.002)
21	0.360 (0.028)	0.143 (0.004)	0.252 (0.016)	0.233 (0.005)	0.064 (0.002)	0.149 (0.002)
22	0.295 (0.058)	0.197 (0.004)	0.246 (0.029)	0.147 (0.021)	0.063 (0.002)	0.105 (0.010)
24	0.484 (0.022)	0.224 (0.004)	0.354 (0.010)	0.220 (0.008)	0.097 (0.006)	0.159 (0.002)
Average	0.252 (0.043)	0.150 (0.021)	0.201 (0.030)	0.189 (0.023)	0.101 (0.013)	0.145 (0.016)

Note: number in parentheses is the standard error of the mean.

Table D.1.3. Bending Properties of Fabric Group 3.

Fabric	B1	B2	B	2HB1	2HB2	2HB
3	0.170 (0.005)	0.126 (0.006)	0.148 (0.005)	0.130 (0.007)	0.145 (0.006)	0.137 (0.006)
5	0.230 (0.008)	0.144 (0.006)	0.187 (0.006)	0.290 (0.011)	0.147 (0.007)	0.219 (0.007)
6	0.274 (0.011)	0.164 (0.011)	0.219 (0.007)	0.228 (0.008)	0.110 (0.007)	0.169 (0.003)
12	0.103 (0.002)	0.062 (0.003)	0.082 (0.002)	0.111 (0.007)	0.053 (0.009)	0.082 (0.008)
13	0.093 (0.002)	0.072 (0.002)	0.082 (0.000)	0.074 (0.002)	0.048 (0.001)	0.061 (0.001)
14	0.149 (0.003)	0.082 (0.002)	0.115 (0.003)	0.124 (0.002)	0.072 (0.002)	0.098 (0.000)
25	0.238 (0.009)	0.129 (0.002)	0.184 (0.006)	0.227 (0.008)	0.066 (0.009)	0.146 (0.009)
26	0.201 (0.016)	0.132 (0.016)	0.167 (0.016)	0.152 (0.015)	0.106 (0.006)	0.129 (0.011)
28	0.118 (0.007)	0.064 (0.006)	0.091 (0.006)	0.069 (0.006)	0.085 (0.002)	0.077 (0.002)
Average	0.174 (0.022)	0.108 (0.013)	0.142 (0.017)	0.156 (0.025)	0.093 (0.012)	0.124 (0.017)

Note: number in parentheses is the standard error of the mean.

Table D.2.1. Compression Properties of Fabric Group 1.

Fabric	LC	WC	RC	T	W
1	0.282 (0.013)	0.205 (0.004)	36.03 (0.772)	0.625 (0.000)	20.480 (0.146)
2	0.304 (0.018)	0.214 (0.003)	38.51 (1.378)	0.683 (0.017)	22.851 (0.006)
7	0.341 (0.001)	0.170 (0.012)	42.03 (0.905)	0.500 (0.017)	18.839 (0.068)
10	0.307 (0.014)	0.159 (0.010)	48.72 (1.124)	0.533 (0.167)	19.569 (0.085)
16	0.281 (0.033)	0.131 (0.006)	43.88 (1.325)	0.583 (0.017)	23.855 (0.020)
17	0.316 (0.008)	0.125 (0.007)	46.20 (0.894)	0.483 (0.008)	21.597 (0.300)
20	0.324 (0.012)	0.201 (0.004)	45.11 (2.363)	0.692 (0.017)	26.396 (0.183)
23	0.335 (0.012)	0.173 (0.012)	50.31 (1.622)	0.617 (0.022)	17.890 (0.022)
27	0.313 (0.011)	0.234 (0.003)	48.39 (1.183)	0.608 (0.017)	17.511 (0.021)
Average	0.311 (0.007)	0.179 (0.059)	44.353 (1.599)	0.592 (0.025)	20.999 (0.985)

Note: number in parentheses is the standard error of the mean.

Table D.2.2. Compression Properties of Fabric Group 2.

Fabric	LC	WC	RC	T	W
4	0.316 (0.012)	0.118 (0.001)	45.09 (1.209)	0.450 (0.014)	18.621 (0.288)
9	0.331 (0.001)	0.193 (0.007)	43.71 (0.293)	0.625 (0.014)	22.259 (0.057)
11	0.327 (0.008)	0.184 (0.008)	52.00 (1.087)	0.633 (0.017)	21.561 (0.044)
15	0.271 (0.006)	0.118 (0.003)	46.51 (0.960)	0.425 (0.000)	16.569 (0.042)
18	0.283 (0.009)	0.235 (0.009)	43.28 (1.561)	0.658 (0.022)	20.715 (0.013)
19	0.317 (0.002)	0.225 (0.007)	48.06 (0.876)	0.650 (0.014)	23.627 (0.026)
21	0.321 (0.023)	0.207 (0.013)	49.08 (2.353)	0.600 (0.014)	17.212 (0.045)
22	0.334 (0.003)	0.160 (0.009)	53.16 (0.687)	0.608 (0.517)	21.620 (0.076)
24	0.333 (0.016)	0.159 (0.002)	56.72 (0.886)	0.642 (0.008)	22.510 (0.062)
Average	0.315 (0.008)	0.178 (0.014)	48.623 (1.526)	0.588 (0.029)	20.521 (0.826)

Note: number in parentheses is the standard error of the mean.

Table D.2.3. Compression Properties of Fabric Group 3.

Fabric	LC	WC	RC	T	W
3	0.309 (0.010)	0.193 (0.006)	44.88 (0.432)	0.650 (0.000)	22.624 (0.038)
5	0.289 (0.021)	0.155 (0.002)	45.75 (2.538)	0.642 (0.017)	24.237 (0.008)
6	0.280 (0.011)	0.163 (0.009)	46.93 (0.898)	0.600 (0.014)	22.237 (0.008)
12	0.318 (0.016)	0.194 (0.024)	44.68 (0.578)	0.575 (0.025)	19.372 (0.070)
13	0.294 (0.014)	0.165 (0.010)	47.93 (0.715)	0.542 (0.017)	18.595 (0.065)
14	0.315 (0.017)	0.183 (0.007)	50.94 (0.472)	0.617 (0.008)	21.838 (0.051)
25	0.271 (0.020)	0.151 (0.004)	36.37 (1.209)	0.600 (0.014)	20.628 (0.259)
26	0.294 (0.013)	0.159 (0.006)	46.68 (1.842)	0.550 (0.014)	18.704 (0.033)
28	0.336 (0.015)	0.250 (0.011)	45.39 (0.740)	0.567 (0.022)	15.864 (0.051)
Average	0.301 (0.007)	0.179 (0.010)	45.507 (1.310)	0.594 (0.013)	20.483 (0.865)

Note: number in parentheses is the standard error of the mean.

Table D.3.1. Surface Properties of Fabric Group 1.

Fabric	MIU1	MIU2	MIU	MMD1	MMD2	MMD	SMD1	SMD2	SMD
1	0.167 (0.001)	0.172 (0.002)	0.169 (0.001)	0.058 (0.004)	0.034 (0.003)	0.046 (0.002)	9.623 (0.137)	3.785 (0.114)	6.704 (0.015)
2	0.166 (0.000)	0.187 (0.001)	0.177 (0.000)	0.010 (0.001)	0.020 (0.002)	0.015 (0.001)	2.253 (0.022)	4.598 (0.357)	3.425 (0.183)
7	0.200 (0.001)	0.196 (0.002)	0.198 (0.001)	0.066 (0.002)	0.025 (0.002)	0.046 (0.002)	8.233 (0.019)	4.078 (0.074)	6.155 (0.046)
10	0.163 (0.003)	0.156 (0.001)	0.160 (0.002)	0.042 (0.003)	0.028 (0.003)	0.035 (0.001)	6.977 (0.244)	4.411 (0.127)	5.694 (0.140)
16	0.162 (0.003)	0.176 (0.005)	0.169 (0.001)	0.013 (0.001)	0.026 (0.001)	0.020 (0.000)	2.736 (0.102)	6.002 (0.100)	4.369 (0.040)
17	0.157 (0.002)	0.182 (0.003)	0.169 (0.002)	0.022 (0.004)	0.020 (0.002)	0.021 (0.003)	12.027 (1.072)	4.056 (0.272)	8.041 (0.623)
20	0.166 (0.000)	0.189 (0.002)	0.178 (0.001)	0.009 (0.000)	0.018 (0.002)	0.014 (0.001)	1.619 (0.100)	3.724 (0.310)	2.672 (0.167)
23	0.183 (0.001)	0.193 (0.004)	0.188 (0.002)	0.012 (0.000)	0.025 (0.004)	0.019 (0.002)	2.243 (0.098)	6.065 (0.091)	4.154 (0.094)
27	0.171 (0.001)	0.180 (0.002)	0.176 (0.001)	0.012 (0.000)	0.018 (0.001)	0.015 (0.001)	2.278 (0.120)	4.072 (0.154)	3.175 (0.114)
Average	0.171 (0.004)	0.181 (0.0600	0.176 (0.004)	0.027 (0.007)	0.024 (0.002)	0.025 (0.004)	5.332 (1.308)	4.532 (0.298)	4.932 (0.604)

Note: number in parentheses is the standard error of the mean.

Table D.3.2. Surface Properties of Fabric Group 2.

Fabric	MIU1	MIU2	MIU	MMD1	MMD2	MMD	SMD1	SMD2	SMD
4	0.217 (0.056)	0.179 (0.018)	0.198 (0.037)	0.066 (0.007)	0.029 (0.005)	0.047 (0.006)	6.884 (0.759)	3.678 (0.419)	5.281 (0.586)
9	0.202 (0.001)	0.203 (0.002)	0.202 (0.002)	0.020 (0.003)	0.016 (0.001)	0.018 (0.002)	12.330 (0.128)	3.920 (0.243)	8.125 (0.177)
11	0.169 (0.003)	0.170 (0.001)	0.170 (0.002)	0.022 (0.002)	0.021 (0.002)	0.021 (0.011)	11.770 (0.779)	4.294 (0.237)	8.032 (0.304)
15	0.160 (0.001)	0.170 (.003)	0.165 (0.001)	0.085 (0.007)	0.052 (0.003)	0.068 (0.004)	11.580 (0.347)	4.697 (0.200)	8.138 (0.075)
18	0.163 (0.001)	0.188 (0.001)	0.175 (0.001)	0.010 (0.000)	0.019 (0.001)	0.014 (0.001)	2.126 (0.131)	4.185 (0.391)	3.155 (0.132)
19	0.167 (0.003)	0.190 (0.002)	0.179 (0.000)	0.011 (0.000)	0.016 (0.001)	0.013 (0.001)	2.069 (0.027)	3.824 (0.306)	2.952 (0.139)
21	0.178 (0.001)	0.196 (0.005)	0.187 (0.002)	0.011 (0.000)	0.041 (0.008)	0.026 (0.004)	2.101 (0.024)	5.376 (0.022)	3.738 (0.023)
22	0.179 (0.001)	0.198 (0.003)	0.189 (0.001)	0.013 (0.002)	0.027 (0.005)	0.020 (0.001)	2.116 (0.205)	4.073 (0.213)	3.095 (0.105)
24	0.150 (0.001)	0.168 (0.004)	0.159 (0.002)	0.104 (0.000)	0.020 (0.001)	0.015 (0.000)	2.033 (0.125)	4.092 (0.225)	3.063 (0.163)
Average	0.176 (0.007)	0.185 (0.004)	0.180 (0.005)	0.028 (0.009)	0.027 (0.004)	0.027 (0.006)	5.890 (1.588)	4.239 (0.172)	5.064 (0.794)

Note: number in parentheses is the standard error of the mean.

Table D.3.3. Surface Properties of Fabric Group 3.

Fabric	MIU1	MIU2	MIU	MMD1	MMD2	MMD	SMD1	SMD2	SMD
3	0.193 (0.001)	0.188 (0.001)	0.190 (0.001)	0.121 (0.007)	0.080 (0.004)	0.100 (0.004)	13.085 (0.512)	8.772 (0.604)	10.928 (0.169)
5	0.172 (0.003)	0.181 (0.003)	0.176 (0.003)	0.013 (0.000)	0.022 (0.001)	0.018 (0.001)	2.838 (0.194)	5.528 (0.127)	4.183 (0.043)
6	0.169 (0.000)	0.174 (0.002)	0.171 (0.001)	0.020 (0.001)	0.020 (0.001)	0.020 (0.001)	12.413 (0.233)	4.101 (0.186)	8.257 (0.120)
12	0.182 (0.001)	0.187 (0.002)	0.185 (0.001)	0.038 (0.001)	0.028 (0.001)	0.033 (0.000)	7.404 (0.274)	4.127 (0.056)	5.765 (0.154)
13	0.181 (0.001)	0.185 (0.003)	0.183 (0.001)	0.052 (0.003)	0.020 (0.001)	0.036 (0.002)	7.723 (0.076)	4.460 (0.210)	6.091 (0.067)
14	0.183 (0.002)	0.194 (0.003)	0.189 (0.002)	0.022 (0.001)	0.023 (0.001)	0.022 (0.000)	12.021 (0.343)	4.157 (0.113)	8.089 (0.214)
25	0.202 (0.002)	0.172 (0.003)	0.187 (0.002)	0.019 (0.001)	0.110 (0.008)	0.064 (0.004)	9.154 (0.868)	10.287 (0.324)	9.720 (0.400)
26	0.176 (0.001)	0.188 (0.002)	0.182 (0.001)	0.011 (0.000)	0.023 (0.003)	0.017 (0.001)	1.913 (0.050)	4.853 (0.151)	3.383 (0.072)
28	0.184 (0.002)	0.196 (0.001)	0.190 (0.001)	0.086 (0.001)	0.027 (0.001)	0.057 (0.000)	9.745 (0.342)	3.318 (0.233)	6.531 (0.268)
Average	0.182 (0.003)	0.185 (0.003)	0.184 (0.002)	0.042 (0.013)	0.039 (0.011)	0.041 (0.009)	8.477 (1.308)	5.511 (0.795)	6.994 (0.827)

Note: number in parentheses is the standard error of the mean.

Table D.4.1. Shear Properties of Fabric Group 1.

Fabric	G1	G2	G	2HG1	2HG2	2HG	2HG5-1	2HG5-2	2HG5
1	2.638 (0.102)	2.667 (0.076)	2.610 (0.128)	4.250 (0.794)	5.033 (1.254)	3.467 (0.334)	6.832 (0.478)	6.253 (1.142)	7.410 (0.209)
2	1.940 (0.016)	1.983 (0.027)	1.897 (0.018)	2.898 (0.024)	3.037 (0.017)	2.760 (0.044)	6.003 (0.051)	6.010 (0.025)	5.997 (0.078)
7	2.925 (0.030)	2.907 (0.052)	2.943 (0.009)	4.737 (0.065)	5.107 (0.064)	4.367 (0.190)	8.313 (0.058)	7.787 (0.055)	8.840 (0.081)
10	3.868 (0.180)	3.810 (0.228)	3.927 (0.133)	2.645 (0.085)	2.903 (0.112)	2.387 (0.066)	11.217 (0.449)	11.010 (0.592)	11.423 (0.350)
16	3.433 (0.045)	3.423 (0.078)	3.443 (0.018)	5.438 (0.314)	5.697 (0.319)	5.180 (0.334)	12.863 (0.061)	12.177 (0.317)	13.550 (0.195)
17	2.357 (0.106)	2.427 (0.122)	2.287 (0.093)	3.163 (0.147)	3.560 (0.144)	2.767 (0.186)	9.240 (0.223)	8.787 (0.219)	9.693 (0.231)
20	2.495 (0.116)	2.540 (0.132)	2.450 (0.100)	4.970 (0.166)	5.390 (0.253)	4.550 (0.112)	9.413 (0.437)	8.977 (0.605)	9.850 (0.270)
23	1.027 (0.115)	1.007 (0.144)	1.047 (0.087)	1.173 (0.055)	1.000 (0.070)	1.347 (0.084)	3.708 (0.375)	3.463 (0.458)	3.953 (0.308)
27	1.275 (0.020)	1.303 (0.027)	1.247 (0.034)	1.318 (0.040)	1.460 (0.031)	1.177 (0.049)	5.068 (0.040)	5.057 (0.031)	5.080 (0.049)
Average	2.4519 (0.305)	2.427 (0.316)	2.440 (0.310)	3.687 (0.577)	3.111 (0.467)	3.399 (0.518)	7.724 (0.941)	8.422 (1.035)	8.073 (0.986)

Note: number in parentheses is the standard error of the mean.

Table D.4.2. Shear Properties of Fabric Group 2.

Fabric	G1	G2	G	2HG1	2HG2	2HG	2HG5-1	2HG5-2	2HG5
4	3.717 (0.276)	3.707 (0.265)	3.727 (0.286)	4.193 (0.206)	4.690 (0.165)	3.697 (0.257)	10.825 (0.598)	10.297 (0.631)	11.353 (0.565)
9	2.418 (0.045)	2.437 (0.044)	2.400 (0.051)	4.938 (0.137)	5.393 (0.179)	4.483 (0.094)	8.768 (0.182)	8.270 (0.356)	9.267 (0.075)
11	2.560 (0.043)	2.590 (0.100)	2.530 (0.021)	3.032 (0.056)	3.313 (0.112)	2.750 (0.017)	9.117 (0.011)	9.107 (0.087)	9.127 (0.088)
15	2.227 (0.064)	2.270 (0.049)	2.183 (0.082)	2.750 (0.120)	3.090 (0.075)	2.410 (0.180)	9.400 (0.116)	9.153 (0.045)	9.647 (0.188)
18	1.615 (0.053)	1.660 (0.051)	1.570 (0.055)	3.022 (0.256)	3.027 (0.242)	3.017 (0.302)	5.372 (0.220)	5.290 (0.203)	5.453 (0.237)
19	1.990 (0.052)	1.993 (0.043)	1.987 (0.062)	3.700 (0.210)	3.873 (0.198)	3.527 (0.225)	7.640 (0.305)	7.410 (0.289)	7.870 (0.321)
21	1.807 (0.064)	1.827 (0.045)	1.787 (0.084)	1.883 (0.048)	1.810 (0.075)	1.957 (0.022)	6.660 (0.154)	6.440 (0.140)	6.880 (0.186)
22	2.072 (0.161)	2.120 (0.190)	2.023 (0.132)	1.942 (0.056)	2.097 (0.069)	1.787 (0.044)	7.163 (0.262)	6.640 (0.187)	7.687 (0.376)
24	2.488 (0.223)	2.590 (0.268)	2.387 (0.229)	1.892 (0.124)	2.010 (0.127)	1.773 (0.120)	7.130 (0.584)	6.997 (0.546)	7.263 (0.669)
Average	2.355 (0.301)	2.288 (0.207)	2.322 (0.204)	3.256 (0.410)	2.822 (0.315)	3.039 (0.360)	7.734 (0.530)	8.283 (0.593)	8.008 (0.554)

Table D.4.3. Shear Properties of Fabric Group 3.

Fabric	G1	G2	G	2HG1	2HG2	2HG	2HG5-1	2HG5-2	2HG5
3	2.498 (0.056)	2.503 (0.072)	2.493 (0.055)	4.233 (0.069)	4.160 (0.081)	4.307 (0.216)	8.625 (0.098)	8.370 (0.017)	8.880 (0.185)
5	2.350 (0.146)	2.440 (0.127)	2.260 (0.169)	4.330 (0.312)	4.627 (0.238)	4.033 (0.416)	8.552 (0.722)	8.353 (0.628)	8.750 (0.828)
6	3.058 (0.102)	3.013 (0.052)	3.103 (0.153)	3.723 (0.039)	3.937 (0.083)	3.510 (0.160)	9.360 (0.168)	8.627 (0.147)	10.093 (0.217)
12	2.198 (0.055)	2.217 (0.052)	2.180 (0.059)	3.587 (0.081)	3.917 (0.142)	3.257 (0.049)	6.877 (0.179)	6.997 (0.191)	6.757 (0.174)
13	1.802 (0.026)	1.880 (0.017)	1.723 (0.041)	2.098 (0.071)	2.297 (0.035)	1.900 (0.115)	4.730 (0.091)	4.693 (0.035)	4.767 (0.147)
14	1.635 (0.066)	1.710 (0.060)	1.560 (0.074)	2.290 (0.068)	2.530 (0.068)	2.050 (0.089)	4.875 (0.114)	4.927 (0.113)	4.823 (0.128)
25	1.678 (0.075)	1.697 (0.122)	1.660 (0.040)	3.325 (0.101)	3.223 (0.113)	3.427 (0.091)	6.702 (0.206)	6.533 (0.279)	6.870 (0.140)
26	1.033 (0.044)	1.043 (0.049)	1.023 (0.050)	1.590 (0.061)	1.430 (0.051)	1.750 (0.072)	4.305 (0.213)	4.307 (0.211)	4.303 (0.252)
28	1.328 (0.023)	1.420 (0.025)	1.237 (0.032)	1.342 (0.099)	1.483 (0.049)	1.200 (0.150)	5.280 (0.076)	5.340 (0.055)	5.220 (0.120)
Average	1.992 (0.203)	1.916 (0.218)	1.954 (0.210)	3.067 (0.398)	2.826 (0.371)	2.947 (0.378)	6.461 (0.572)	6.718 (0.704)	6.589 (0.636)

Note: number in parentheses is the standard error of the mean.

Table D.5.1. Tensile Properties of Fabric Group 1.

Fabric	LT1	LT2	LT	WT1	WT2	WT	RT1	RT2	RT
1	0.717	0.745	0.731	6.583	6.817	6.700	57.738	63.434	60.586
	(0.014)	(0.011)	(0.003)	(0.164)	(0.646)	(0.263)	(1.132)	(0.612)	(0.645)
2	0.685	0.741	0.713	5.917	11.050	8.483	54.935	57.371	56.153
	(0.007)	(0.001)	(0.004)	(0.088)	(0.275)	(0.098)	(0.750)	(1.153)	(0.802)
7	0.706	0.761	0.733	4.217	12.568	8.392	59.734	58.889	59.311
	(0.008)	(0.003)	(0.005)	(0.130)	(0.060)	(0.088)	(0.823)	(0.403)	(0.516)
10	0.694	0.808	0.751	4.400	7.817	6.108	59.883	58.648	59.265
	(0.011)	(0.012)	(0.011)	(0.087)	(0.169)	(0.088)	(1.298)	(0.627)	(0.589)
16	0.666	0.734	0.700	3.733	10.983	7.358	55.390	50.531	52.961
	(0.009)	(0.004)	(0.004)	(0.109)	(0.017)	(0.060)	(0.784)	(0.273)	(0.434)
17	0.700	0.700	0.700	3.700	9.367	6.533	58.129	58.925	58.527
	(0.012)	(0.018)	(0.004)	(0.050)	(0.142)	(0.085)	(0.796)	(1.036)	(0.865)
20	0.684	0.722	0.703	4.900	12.967	8.933	48.665	53.474	51.069
	(0.027)	(0.008)	(0.011)	(0.104)	(0.088)	(0.008)	(1.005)	(0.672)	(0.748)
23	0.706	0.779	0.742	2.517	30.417	16.667	62.983	39.085	51.034
	(0.012)	(0.007)	(0.003)	(0.067)	(1.403)	(0.670)	(1.430)	(1.371)	(0.597)
27	0.683	0.748	0.715	3.317	4.683	4.000	63.359	64.768	64.063
	(0.021)	(0.016)	(0.004)	(0.060)	(0.017)	(0.025)	(1.164)	(0.126)	(0.627)
Ave.	0.693	0.748	0.721	4.365	11.852	8.108	57.868	56.125	56.996
	(0.005)	(0.011)	(0.006)	(0.425)	(2.492)	(1.159)	(1.566)	(2.583)	(1.506)

Note: number in parentheses is the standard error of the mean.

Table D.5.2. Tensile Properties of Fabric Group 2.

Fabric	LT1	LT2	LT	WT1	WT2	WT	RT1	RT2	RT
4	0.689 (0.037)	0.797 (0.013)	0.743 (0.024)	3.783 (0.109)	11.417 (0.167)	7.600 (0.138)	59.991 (1.614)	55.638 (0.700)	57.814 (1.156)
9	0.725 (0.011)	0.684 (0.004)	0.704 (0.005)	5.183 (0.044)	9.033 (0.093)	7.108 (0.051)	53.710 (0.731)	57.748 (0.090)	55.729 (0.331)
11	0.720 (0.013)	0.794 (0.021)	0.757 (0.005)	4.683 (0.093)	6.683 (0.109)	5.683 (0.017)	58.372 (0.288)	56.368 (0.301)	57.370 (0.112)
15	0.687 (0.023)	0.744 (0.012)	0.716 (0.006)	4.400 (0.058)	5.100 (0.104)	4.750 (0.038)	60.222 (0.605)	62.422 (0.107)	61.322 (0.356)
18	0.675 (0.004)	0.669 (0.006)	0.672 (0.001)	5.183 (0.044)	16.467 (0.301)	10.825 (0.128)	58.521 (0.419)	56.095 (0.777)	57.308 (0.527)
19	0.662 (0.015)	0.709 (0.006)	0.686 (0.006)	5.600 (0.029)	11.517 (0.186)	8.558 (0.096)	55.676 (0.244)	55.595 (0.726)	54.135 (0.340)
21	0.714 (0.013)	0.786 (0.029)	0.750 (0.010)	2.950 (0.076)	16.200 (0.695)	9.575 (0.384)	60.522 (1.473)	55.513 (2.033)	58.018 (1.742)
22	0.636 (0.018)	0.798 (0.005)	0.717 (0.011)	2.850 (0.275)	23.433 (1.545)	13.142 (0.773)	66.378 (1.737)	54.545 (1.026)	60.461 (0.739)
24	0.742 (0.026)	0.840 (0.016)	0.791 (0.010)	3.367 (0.073)	25.417 (0.897)	14.392 (0.438)	59.937 (0.865)	54.930 (1.619)	57.433 (0.558)
Ave.	0.695 (0.011)	0.758 (0.020)	0.726 (0.013)	4.222 (0.342)	13.919 (2.358)	9.070 (1.084)	58.926 (1.337)	56.539 (0.796)	57.732 (0.724)

Note: number in parentheses is the standard error of the mean.

Table D.5.3. Tensile Properties of Fabric Group 3.

Fabric	LT1	LT2	LT	WT1	WT2	WT	RT1	RT2	RT
3	0.725 (0.013)	0.737 (0.005)	0.731 (0.005)	5.367 (0.101)	10.833 (0.240)	8.100 (0.138)	54.365 (0.738)	56.907 (0.308)	55.636 (0.176)
5	0.658 (0.057)	0.685 (0.014)	0.672 (0.033)	4.017 (0.317)	13.367 (0.088)	8.692 (0.137)	57.144 (4.549)	53.728 (1.118)	55.436 (2.813)
6	0.686 (0.005)	0.738 (0.001)	0.712 (0.004)	3.800 (0.161)	9.133 (0.044)	6.467 (0.102)	61.463 (0.715)	60.037 (0.239)	60.750 (0.396)
12	0.670 (0.014)	0.737 (0.012)	0.704 (0.006)	8.583 (0.595)	10.150 (0.208)	9.367 (0.393)	52.641 (2.988)	61.586 (0.234)	57.114 (1.606)
13	0.636 (0.004)	0.742 (0.018)	0.689 (0.011)	6.150 (0.029)	13.050 (0.132)	9.600 (0.072)	62.062 (0.396)	64.120 (0.440)	63.091 (0.309)
14	0.663 (0.004)	0.671 (0.006)	0.667 (0.002)	6.117 (0.219)	9.567 (0.088)	7.842 (0.067)	58.355 (0.767)	62.368 (0.077)	60.362 (0.396)
25	0.729 (0.020)	0.721 (0.003)	0.725 (0.010)	3.333 (0.130)	19.550 (0.306)	11.442 (0.116)	52.084 (1.402)	55.596 (0.485)	53.840 (0.558)
26	0.706 (0.001)	0.763 (0.008)	0.735 (0.004)	2.967 (0.142)	7.500 (0.153)	5.233 (0.116)	59.845 (3.113)	56.660 (0.297)	58.253 (1.429)
28	0.677 (0.016)	0.736 (0.014)	0.706 (0.010)	3.550 (0.058)	4.967 (0.033)	4.258 (0.033)	65.320 (2.125)	67.449 (0.029)	66.384 (0.950)
Ave.	0.683 (0.011)	0.726 (0.010)	0.705 (0.008)	4.876 (0.610)	10.911 (1.383)	7.889 (0.752)	58.142 (1.505)	59.828 (1.490)	58.985 (1.349)

Note: number in parentheses is the standard error of the mean.

APPENDIX E. EXPLANATION AND DEFINITION OF RELIABILITY AND VALIDITY.

E.1. Multitrait-Multimethod Matrix Analysis of Validity and Variance.

E.1.1. Convergent and Discriminant Validity.

Validity is concerned with whether an instrument or method measures what it is intended to measure. When more than one method is used to measure more than one attribute, a multitrait-multimethod matrix is a means of evaluating convergent and discriminant validity.

Convergent validity is established when there is good correlation between measurements of one attribute or trait by different methods. In a multitrait-multimethod matrix, convergent validity is determined by looking at the validity diagonals in a matrix. There is one validity diagonal in each heteromethod block and it separates the two different trait-different method triangles (defined by dotted lines). Only if values on the validity diagonals are high, .50 or higher, is further analysis of the matrix warranted.

Evidence of discriminant validity is obtained in three different ways. A value on a validity diagonal should be higher than the values found in its row and column in the adjoining different trait-different method triangles. This indicates that the correlation between measurements of an attribute by two different methods is higher than the correlation between measurements in which both traits and methods are different. As an example from this study, in order to establish discriminant validity, it would be necessary that the correlation between the measurements of flexibility by rating scale and rank order methods be higher than the correlation between the measurement of flexibility by the rating scale method and the measurement of surface roughness by the rank order method. If the value in the validity diagonal is not higher, then there is insufficient evidence that judges are making two different measurements, and the measurement would not be judged valid.

Discriminant validity is also evaluated by comparing the values in the validity diagonal with values in corresponding different trait-same method triangles (in solid lines). It is expected that the correlation between measurements of one trait using different methods would be higher than measurements of two different traits that use the same method. For example, measurements of fabric weight evaluated by rating scale and paired comparison methods should be higher that the correlation between measurements of fabric weight and thickness using the rating scale method.

A third determination of discriminant validity is made by examining the pattern of interrelationship between traits in the triangles. It is possible that the values in one triangle will all be lower than the corresponding values in another triangle. If, however, the correlation of the measurements of fabric flexibility and weight by the rating scale method are lower than the measurements of weight and thickness and weight by the rating scale method, the same relationship between the correlation of trait measurements should be found in the other different trait triangles. If the pattern is not consistent across all triangles, there is evidence that a characteristic of the measurement process other than the traits themselves are contributing to differences in the correlations and discriminant validity would not be established.

E.1.2. <u>Method and Trait Variance</u>.

The data presented in a multitrait-multimethod matrix also allows one to determine whether there is a difference in the measurement methods being used or a difference in the traits or attributes being subjectively measured. These concepts are referred to as method and trait variance, respectively.

The presence of method variance is indicated by differences in the levels of correlation between different traits measured by the same method and the different traits measured by different methods. If there were a difference between the rank order and paired comparison methods, it would be expected that the correlation of the measurements of flexibility and weight by the rank order method would be higher than the correlation of the measurement of flexibility by the rank order method with the correlation of measurement of weight by the paired comparison method.

If there were evidence of difference between methods, it would be necessary to examine the methods in order to determine whether factors intrinsic to the method are contributing to measurement error. If systematic factors related to a method are found, measurements using those methods would be invalid.

Trait variance is established when the correlation between the measurements of one trait evaluated by two different methods is different and higher than the correlation between the measurements of two different traits measured by two different methods. The correlation between the subjective measurement of flexibility by rating scale and rank order methods is expected to be higher than the correlation between the measurement of flexibility by the rating scale method and the measurement of surface roughness by the rank order method. Correlations that are different provide evidence that two different traits are being measured.

E.2. Reliability.

Reliability is concerned with the repeatability of a measurement. The reliability coefficients discussed in this paper are expressed as a measure of internal consistency. These coefficients are presented in Tables 5.1., 5.2. and 5.3. and were calculated from the data obtained from the analyses of variance carried out for each fabric group and for each attribute-method pair.

The reliability coefficients were calculated as follows:

Source	df	SS	MS	E(MS)
Fabric	a-1		MS_F	$\sigma_E^2 + n\sigma_F^2$
Judge	n-1		MS_J	$\sigma_E^2 + a\sigma_J^2$
Error	(a-1)(n-1)		MS_E	σ_E^2
Total	an-1			

a = number of fabrics
n = number of judges

Reliability is the ratio of the true variance of a scale value to the total variance of a score value or:

$$\sigma_F^2\,\text{true}/\sigma_F^2\,\text{total}$$

The true variance ($\sigma_F^2{}_{\text{true}}$) and total variance ($\sigma_F^2{}_{\text{total}}$) of the fabric scale values were determined as follows:

$$\sigma_{F}^{2}\text{true} = (MS_F - \sigma_{E}^{2})/n$$

$$\sigma_{F}^{2}\text{total} = \sigma_{F}^{2}\text{true} + \sigma_{E}^{2}$$

The reliability, r_I, expressed as $\sigma_{F^2}\text{true}/\sigma_{F}^{2}\text{total}$ is referred to as an intraclass correlation and represents the proportion of variance shared between the true scale values and the observed scale values for fabrics evaluated subjectively.

The general form of the Spearman Brown Prophecy Formula determines the reliability of scale scores across judges for a particular method and attribute:

$$r_{SB} = nr_I/[1 + (n-1)r_I]$$

where r_I is the intraclass correlation and n represents the number of judges. It is this reliability coefficient that was placed on the main diagonals of Tables 5.1., 5.2, and 5.3.

If a desired or acceptable reliability is know the Spearman Brown Prophecy Formula can be rearranged to allow the determination of the number of judges required to give that reliability:

$$n = r(1-r_I)/r_I(1-r).$$

The Spearman Brown reliability coefficient, the intraclass correlation and the number of judges required to give a reliability coefficient of .90 for the data obtained in this study are presented in Table 6. in the text.

APPENDIX F. CORRELATION BETWEEN KES PROPERTY MEASUREMENTS.

Table F.1. Correlation Between KES Properties of Fabric Group 1.

KES	LC	WC	RC	T	W	B	2HB	MIU	MMD	SMD	G	2HG	2HG5	LT	WT	RT
LC	1.00	0.03	0.47	-0.21	-0.31	-0.22	-0.41	0.74*	-0.06	-0.08	-0.38	-0.30	-0.38	0.25	0.46	0.15
WC		1.00	-0.25	0.69	-0.14	-0.55	-0.52	0.18	-0.13	-0.58	-0.51	-0.31	-0.65	0.10	-0.12	0.30
RC			1.00	-0.27	-0.32	0.57	0.11	-0.02	-0.42	-0.19	-0.21	-0.54	-0.01	0.17	0.24	0.16
T				1.00	0.43	-0.03	0.02	0.00	-0.48	-0.78*	-0.39	-0.02	-0.36	-0.20	0.23	-0.39
W					1.00	0.20	0.50	-0.26	-0.36	-0.25	0.34	0.69*	0.54	-0.68*	-0.08	-0.57
B						1.00	0.79*	-0.36	-0.43	-0.23	0.22	-0.01	0.45	-0.09	0.27	-0.56
2HB							1.00	-0.23	-0.30	-0.23	0.44	0.51	0.69	-0.44	0.00	-0.51
MIU								1.00	0.10	-0.17	-0.44	0.00	-0.48	0.12	0.53	-0.18
MMD									1.00	0.66	0.50	0.31	0.14	0.58	-0.16	0.43
SMD										1.00	0.37	0.14	0.24	0.18	-0.20	0.38
G											1.00	0.67*	0.90*	0.08	-0.42	0.04
2HG												1.00	0.69*	-0.40	-0.22	-0.26
2HG5													1.00	-0.27	-0.41	-0.15
LT														1.00	0.30	0.20
WT															1.00	0.74*
RT																1.00

Note: * indicates significance at the .05 level or less.

Table F.2. Correlation Between KES Properties of Fabric Group 2.

KES	LC	WC	RC	T	W	B	2HB	MIU	MMD	SMD	G	2HG	2HG5	LT	WT	RT
LC	1.00	0.09	0.55	0.48	0.56	0.70*	0.62	0.33	−0.59	−0.17	0.25	0.00	0.04	0.48	0.39	0.36
WC		1.00	−0.17	0.83*	0.46	−0.07	0.21	0.05	−0.78*	−0.38	−0.70*	0.04	−0.73*	−0.47	0.19	0.65
RC			1.00	0.29	0.30	0.87*	0.08	−0.52	−0.27	−0.31	−0.02	−0.71*	−0.17	0.71*	0.55	0.19
T				1.00	0.76*	0.39	0.40	−0.09	−0.97*	−0.43	−0.55	−0.13	−0.71*	−0.11	0.50	0.59
W					1.00	0.26	0.40	−0.02	−0.80*	−0.27	−0.10	0.22	−0.25	−0.13	0.39	0.65
B						1.00	0.45	−0.31	−0.39	−0.12	0.07	−0.55	−0.13	0.84*	0.46	0.06
2HB							1.00	0.23	−0.47	0.48	0.21	0.41	0.23	0.32	−0.23	0.51
MIU								1.00	−0.06	0.08	0.28	0.57	0.25	−0.30	−0.13	0.22
MMD									1.00	0.51	0.40	0.05	0.64	0.08	−0.57	0.64
SMD										1.00	0.34	0.48	0.68*	0.06	−0.83*	0.17
G											1.00	0.43	0.85*	0.45	−0.26	0.01
HG												1.00	0.53	−0.42	−0.56	0.54
2HG5													1.00	0.25	−0.66	0.11
LT														1.00	0.21	0.20
WT															1.00	0.01
RT																1.00

Note: * indicates significance at the .05 level or less.

Table F.3. Correlation Between KES Properties of Fabric Group 3.

KES	LC	WC	RC	T	W	B	2HB	MIU	MMD	SMD	G	2HG	2HG5	LT	WT	RT
LC	1.00	0.90*	0.42	-0.11	-0.49	-0.75*	-0.60	0.59	0.18	-0.09	-0.29	-0.39	-0.33	-0.19	-0.49	0.53
WC		1.00	0.17	-0.12	-0.58	-0.60	-0.53	0.56	0.36	0.11	-0.21	-0.38	-0.19	0.01	-0.54	0.61
RC			1.00	-0.09	-0.04	-0.29	-0.24	-0.17	-0.48	-0.33	0.03	-0.29	-0.24	-0.52	-0.49	0.54
T				1.00	0.84*	0.46	0.66	0.01	0.33	0.50	0.56	0.76*	0.71*	-0.17	0.23	0.56
W					1.00	0.64	0.7*	-0.42	-0.06	0.27	0.68*	0.82*	0.71*	-0.26	0.38	0.65
B						1.00	0.88*	-0.61	-0.13	0.14	0.42	0.48	0.60	0.27	0.00	0.50
2HB							1.00	-0.58	-0.14	-0.01	0.48	0.66	0.70*	0.01	0.09	0.60
MIU								1.00	0.66	0.39	-0.53	-0.33	-0.46	0.15	0.06	0.07
MMD									1.00	0.73*	0.07	0.21	0.21	0.50	0.19	0.19
SMD										1.00	0.38	0.36	0.39	0.26	0.32	-0.20
G											1.00	0.83*	0.91*	-0.08	0.24	0.26
2HG												1.00	0.90*	-0.02	0.52	0.72*
2HG5													1.00	0.09	0.19	-0.45
LT														1.00	-0.16	-0.23
WT															1.00	-0.62
RT																1.00

Note: * indicates significance at the .05 level or less.

APPENDIX G. CORRELATIONS BETWEEN SUBJECTIVE AND OBJECTIVE HAND MEASUREMENTS

Table G.1.1. Correlation of KES Properties with Rating Scale Evaluations for Fabric Group 1.

KES	Flexibility	Surface	Weight	Thickness
LT	-0.30	-0.35	-0.55	-0.71*
WT	-0.15	-0.08	-0.11	-0.17
RT	-0.34	-0.39	-0.56	-0.51
B	0.60	0.79*	0.52	0.42
2HB	0.76*	0.80*	0.77*	0.79*
G	0.74*	0.57	0.58	0.45
2HG	0.55	0.39	0.71*	0.75*
2HG5	0.90*	0.80*	0.79*	0.69*
LC	-0.45	-0.44	-0.47	-0.47
WC	-0.82*	-0.81*	-0.44	-0.27
RC	0.06	0.23	-0.18	-0.25
MIU	-0.54	-0.56	-0.43	-0.30
MMD	0.01	-0.17	-0.26	-0.33
SMD	0.32	0.22	-0.12	-0.26
T	-0.35	-0.30	-0.19	-0.30
W	0.52	0.45	0.90*	0.91*

Note: * indicates significance at the .05 level or less.

Table G.1.2. Correlation of KES Properties with Rating Scale Evaluations for Fabric Group 2.

KES	Flexibility	Surface	Weight	Thickness
LT	0.92*	0.69*	0.38	0.52
WT	-0.04	-0.41	0.23	0.37
RT	0.27	0.44	-0.54	-0.46
B	0.72*	0.33	0.56	0.76*
2HB	0.39	0.14	0.74*	0.76*
G	0.60	0.63	0.33	0.13
2HG	-0.21	-0.09	0.28	0.02
2HG5	0.52	0.71*	0.15	-0.06
LC	0.39	-0.06	0.76*	0.83*
WC	-0.65	-0.77*	0.07	0.17
RC	0.62	0.30	0.41	0.58
MIU	-0.30	-0.36	0.35	-0.06
MMD	0.25	0.64	-0.57	-0.65
SMD	0.37	0.57	0.08	-0.02
T	-0.26	-0.61	0.50	0.62
W	-0.10	-0.41	0.78*	0.70*

Note: * indicates significance at .05 level or less.

Table G.1.3. Correlation of KES Properties with Rating Scale Evaluations for Fabric Group 3.

KES	Flexibility	Surface	Weight	Thickness
LT	0.12	0.09	0.05	0.01
WT	0.32	0.40	0.35	0.27
RT	-0.63	-0.70*	-0.65	-0.62
B	0.82*	0.75*	0.81*	0.80*
HB	0.80*	0.78*	0.86*	0.84*
G	0.76	0.57	0.71*	0.67*
2HG	0.83*	0.78*	0.84*	0.80*
2HG5	0.86*	0.73*	0.83*	0.81*
LC	-0.62	-0.59	-0.64	-0.52
WC	-0.51	-0.51	-0.55	-0.43
RC	-0.27	-0.33	-0.27	-0.24
MIU	-0.43	-0.20	-0.43	-0.33
MMD	0.15	0.31	0.17	0.17
SMD	0.32	0.26	0.19	0.29
T	0.79*	0.85*	0.80*	0.87*
W	0.87*	0.87*	0.90*	0.90*

Note: * indicates significance at .05 or less.

Table G.2.1. Correlation of KES Properties with Rank Order Evaluations for Fabric Group 1.

KES	Flexibility	Surface	Weight	Thickness
LT	-0.27	-0.20	-0.61	-0.58
WT	-0.07	-0.06	-0.26	-0.23
RT	-0.42	-0.35	-0.42	-0.44
B	0.65	0.75*	0.39	0.35
HB	0.75*	0.75*	0.73*	0.72*
G	0.73*	0.62	0.63	0.67*
2HG	0.59	0.41	0.75*	0.81*
2HG5	0.88*	0.77*	0.80*	0.83*
LC	-0.43	-0.54	-0.52	-0.43
WC	-0.81*	-0.79*	-0.40	-0.43
RC	0.03	0.11	-0.30	-0.31
MIU	-0.50	-0.60	-0.45	-0.34
MMD	0.05	0.00	-0.21	-0.13
SMD	0.32	-0.31	-0.08	-0.04
T	-0.30	-0.29	0.15	0.09
W	0.55	0.39	0.89*	0.88*

Note: * indicates significance at .05 level or less.

Table G.2.2. Correlation of KES Properties with Rank Order Evaluations for Fabric Group 2.

KES	Flexibility	Surface	Weight	Thickness
LT	0.87*	0.67*	0.34	0.39
WT	-0.11	-0.47	0.24	0.30
RT	0.37	0.29	-0.61	-0.55
B	0.66	0.36	0.62	0.63
HB	0.28	0.23	0.78*	0.76*
G	0.55	0.50	0.17	0.19
2HG	-0.27	-0.10	0.19	0.18
2HG5	0.54	0.64	0.01	0.00
LC	0.30	-0.04	0.83*	0.77*
WC	-0.69*	0.62	0.27	0.18
RC	-.64	0.36	0.45	0.46
MIU	-0.38	-0.47	0.05	-0.02
MMD	0.04	0.55	-0.71*	-0.65
SMD	0.40	0.59	0.01	0.03
T	-0.33	-0.48	-0.66	0.61
W	-0.15	-0.32	0.81*	0.80*

Note: * indicates significance at .05 level or less.

Table G.2.3. Correlation of KES Properties with Rank Order Evaluations for Fabric Group 3.

KES	Flexibility	Surface	Weight	Thickness
LT	0.07	0.24	-0.06	-0.05
WT	0.30	0.42	0.29	0.34
RT	-0.63	-0.71*	-0.65	-0.68*
B	0.89*	0.74*	0.85*	0.84*
HB	0.87*	0.73*	0.91*	-0.71*
G	0.71*	0.70*	0.69*	-0.67*
2HG	0.79*	0.84*	0.81*	0.82*
2HG5	0.81*	0.81*	0.79*	0.78*
LC	-0.72*	0.84*	0.81*	0.82*
WC	-0.63	-0.54	-0.64	-0.64
RC	-0.23	-0.35	-0.13	-0.18
MIU	-0.56	-0.29	-0.58	-0.52
MMD	-0.01	0.33	-0.10	-0.03
SMD	0.35	0.56	0.23	0.28
T	0.70*	0.75*	0.75*	0.78*
W	0.88*	0.83*	0.94*	0.94*

Note: * indicates significance at .05 level or less.

Table G.3.1. Correlation of KES Properties with Paired Comparison Evaluations for Fabric Group 1.

KES	Flexibility	Surface	Weight	Thickness
LT	-0.29	-0.26	-0.61	-0.42
WT	-0.21	-0.02	-0.12	-0.15
RT	-0.33	-0.40	-0.58	-0.74*
B	0.60	0.87*	0.56	0.47
HB	0.68*	0.80*	0.80*	0.73*
G	0.77*	0.49	0.47	0.48
2HG	0.58	0.23	0.62	0.68*
2HG5	0.93*	0.72*	0.71*	0.64
LC	-0.38	-0.44	-0.40	-0.20
WC	-0.76*	-0.77*	-0.29	-0.32
RC	0.10	0.32	-0.06	-0.16
MIU	-0.57	-0.59	-0.38	-0.11
MMD	0.02	-0.25	-0.43	-0.28
SMD	0.29	0.14	-0.35	-0.34
T	-0.31	-0.26	0.32	0.32
W	0.57	0.36	0.89*	0.86*

Note: * indicates significance at .05 level or less.

Table G.3.2. Correlation of KES Properties with Paired Comparison Evaluations for Fabric Group 2.

KES	Flexibility	Surface	Weight	Thickness
LT	0.84*	0.65	0.24	0.44
WT	-0.18	-0.45	0.47	0.28
RT	0.23	0.45	-0.42	-0.46
B	0.61	0.29	0.58	0.76*
HB	0.36	0.12	0.58	0.80*
G	0.21	0.59	0.11	0.05
2HG	-0.13	-0.09	0.09	0.00
2HG5	0.62	0.72*	-0.13	-0.09
LC	0.31	-0.09	0.76*	0.85*
WC	-0.66	-0.79*	0.21	0.28
RC	0.57	0.30	0.48	0.56
MIU	-0.36	-0.78*	0.02	0.00
MMD	0.32	0.68*	-0.74*	-0.71*
SMD	0.44	0.61	-0.13	-0.02
T	-0.32	-0.64	0.67*	-0.69*
W	-0.08	-0.42	0.87*	0.71*

Note: * indicates significance at .05 level or less.

Table G.3.3. Correlation of KES Properties with Paired Comparison Evaluations for Fabric Group 3.

KES	Flexibility	Surface	Weight	Thickness
LT	0.12	0.28	0.16	-0.04
WT	0.36	0.37	0.24	0.17
RT	-0.63	-0.68*	-0.68*	-0.52
B	0.82*	0.74*	0.88*	0.83*
HB	0.81*	0.68*	0.89*	0.88*
G	0.70*	0.62	0.69*	0.73*
2HG	0.80	0.75*	0.80*	0.78*
2HG5	0.82*	0.73*	0.80*	0.84*
LC	-0.66*	-0.60	-0.59	-0.56
WC	0.52	-0.49	-0.51	-0.48
RC	-0.35	-0.36	-0.24	-0.08
MIU	-0.38	-0.19	-0.38	-0.52
MMD	0.21	0.38	0.17	0.04
SMD	0.54	0.66	0.45	0.34
T	0.82*	0.76*	0.81*	0.85*
W	0.85*	0.79*	0.89*	0.91*

Note: * indicates significance at .05 level or less.

APPENDIX H. STEPWISE BLOCK REGRESSION ANALYSES.

Table H.1.1. Stepwise Block Regression Analysis of Flexibility for Fabric Group 1.

STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6	
Dep. variable: Flexibility Score		Step #1 Residuals		Step #2 Residuals		Step #3 Residuals		Step #4 Residuals		Step #5 Residuals	
Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2
Compression	.825	Tensile	.742	Bending	.280	Surface	.258	Shear	.124	Thickness & Weight	.003
Shear	.790	Thickness & Weight	.583	Shear	.274	Thickness & Weight	.174	Thickness & Weight	.119		
Thickness & Weight	.643	Shear	.374	Surface	.259	Shear	.135				
Bending	.564	Surface	.245	Thickness & Weight	.112						
Tensile	.544	Bending	.158								
Surface	.316										

Table H.1.2. Stepwise Block Regression Analysis of Flexibility for Fabric Group 2.

STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6	
Dep. variable: Flexibility Score		Step #1 Residuals		Step #2 Residuals		Step #3 Residuals		Step #4 Residuals		Step #5 Residuals	
Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2
Tensile	.883	Thickness & Weight	.687	Surface	.593	Shear	.225	Compression	.045	Bending	.065
Compression	.775	Surface	.213	Compression	.534	Bending	.145	Bending	.020		
Shear	.754	Compression	.179	Shear	.475	Compression	.091				
Bending	.442	Shear	.081	Bending	.158						
Surface	.347	Bending	.018								
Thickness & Weight	.135										

Table H.1.3. Stepwise Block Regression Analysis of Flexibility for Fabric Group 3.

STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6	
Dep. variable: Flexibility Score		Step #1 Residuals		Step #2 Residuals		Step #3 Residuals		Step #4 Residuals		Step #5 Residuals	
Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2
Bending	.819	Shear	.788	Surface	.458	Compression	.097	Tensile	.094	Thickness & Weight	.026
Thickness & Weight	.785	Surface	.559	Compression	.180	Thickness & Weight	.065	Thickness & Weight	.008		
Surface	.712	Tensile	.394	Thickness & Weight	.168	Tensile	.068				
Shear	.675	Thickness & Weight	.301	Tensile	.009						
Compression	.531	Compression	.058								
Tensile	.423										

Table H.2.1. Stepwise Block Regression Analysis of Weight for Fabric Group 1.

STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6	
Dep. variable: Weight Score		Step #1 Residuals		Step #2 Residuals		Step #3 Residuals		Step #4 Residuals		Step #5 Residuals	
Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2
Tensile	.890	Compression	.814	Shear	.482	Bending	.104	Surface	.105	Thickness & Weight	.040
Thickness & Weight	.860	Surface	.329	Thickness & Weight	.311	Surface	.068	Thickness & Weight	.031		
Shear	.784	Shear	.279	Bending	.162	Thickness & Weight	.004				
Bending	.626	Bending	.143	Surface	.014						
Compression	.450	Thickness & Weight	.140								
Surface	.230										

Table H.2.2. Stepwise Block Regression Analysis of Weight for Fabric Group 2.

STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6	
Dep. variable: Weight Score		Step #1 Residuals		Step #2 Residuals		Step #3 Residuals		Step #4 Residuals		Step #5 Residuals	
Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2
Compression	.738	Surface	.602	Thickness & Weight	.606	Shear	.456	Bending	.194	Tensile	.163
Bending	.705	Thickness & Weight	.360	Shear	.568	Bending	.154	Tensile	.080		
Surface	.689	Bending	.279	Tensile	.173	Tensile	.151				
Thickness & Weight	.610	Tensile	.266	Bending	.122						
Tensile	.610	Shear	.217								
Shear	.143										

Table H.2.3. Stepwise Block Regression Analysis of Weight for Fabric Group 3.

STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6	
Dep. variable: Weight Score		Step #1 Residuals		Step #2 Residuals		Step #3 Residuals		Step #4 Residuals		Step #5 Residuals	
Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2	Blocked Property	R^2
Thickness & Weight	.894	Shear	.702	Compression	.620	Bending	.434	Surface	.593	Tensile	.281
Bending	.831	Compression	.661	Bending	.460	Tensile	.270	Tensile	.027		
Shear	.678	Bending	.569	Tensile	.316	Surface	.220				
Surface	.586	Tensile	.393	Surface	.247						
Tensile	.542	Surface	.361								
Compression	.452										