A SENSORY EVALUATION METHOD FOR PHYSICAL PROPERTIES RELATED TO FABRIC HAND

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Abstract

The focus of this exploratory research was to develop and evaluate a method of assessing physical properties related to fabric hand. The method developed used commonly understood terminology, standardized handling techniques and interval scales containing fabrics as standard references, using the basic principles of the Texture Profile method. Hand characteristics examined were flexibility, compressibility, thickness, weight, surface friction, surface contour and surface texture.

During the development stages, group discussions and small panels were used to collect and refine terminology and handling techniques for each of the characteristics. Then, interval rating scales were established by selecting fabric samples as reference standards. They represented the increase in magnitude of the characteristic along the scale.

To evaluate the method, a trained panel assessed a range of apparel fabrics. Panelist and panel

reliability were determined using analysis of variance. The values from this trial were also used to determine the correlation between the sensory evaluation of the characteristics and the corresponding instrumental measurements. The values from the test trial were also used to construct fabric hand profiles.

The analyses to determine the reliability of the panelist and panel showed that the sensory procedures were reliable. The correlations between the sensory evaluation and instrumental measurement values showed good linear associations for weight, thickness, flexibility, and compressibility. The correlation for surface friction did not demonstrate a linear association.

The panel results were shown to be effective in the development of fabric hand profiles. These profiles can be applied in quality control procedures used in the manufacture of textile products, in development and improvement of textile products, and in providing knowledge about fabric hand.

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CHAPTER ONE

INTRODUCTION

The sensory characteristics of the environment may be measured by the five senses people use to obtain information about their surroundings. In general, visual and audio are the dominant senses relaying the majority of information, with tactile largely being forgotten by people. Distinction has been made dividing the senses into higher (e.g., vision and audition) and lower (e.g., touch) levels (Krueger, 1970).

For the sensory characteristics to be accurately delineated, the characteristics need to be quantified. While instrumental measurements would provide quantitative measures of the characteristics, a sensory evaluation of the characteristics gives values or appraisal measured by the human senses and is the only method that gives a true description of the relevant physical characteristics of fabrics as they are perceived by the human senses. An instrumental measurement cannot give information on human responses unless it has good correlation with a sensory evaluation.

Psychophysics directly concerns the correlation of sensory experience with instrumental measures. The ultimate goal is to develop mathematical relations that permit the prediction of sensory characteristics from instrumental measurements and vice versa (Moskowitz, Drake and Akesson, 1972). Estimates can also be used to predict property levels associated with the preferences of a person and to provide information to help make decisions concerning various production processes. Before the correlation of sensory evaluation with instrumental measures is possible, the sensory procedures must be developed into objective methods that eliminate those cultural and psychological factors that may influence a person's response.

Development of sensory evaluation has occurred more swiftly in some areas than others. The foods area may be used to illustrate progression in the development of sensory evaluation. Tea tasters, in China, have for a long time judged the preference for teas on the basis of like-dislike. The components of the beverage are not taken into consideration. Wine tasters, for example, have also judged the preference of wines taking into account the various components. Further developments of sensory evaluation in the foods area have produced the profile methods, which are objective methods of judging food products which do not depend on personal preference or require final judgment as to the quality. The Texture Profile method, for example, is used to analyze the texture complex in terms of the mechanical, geometrical, fat and moisture characteristics, according to the degree of each present and the order of appearance from first bite through complete mastication to obtain a complete record of the texture of a food product. The Texture Profile method can be used for quality control, product development and improvement, and texture education (Brandt, 1963).

In textiles, the analysis of the tactile complex is termed fabric hand. The touch process allows information to be obtained about the qualities of the textiles related to feel such as temperature, surface characteristics, thickness and weight. However, developments of sensory evaluation in the textiles area has been slower than in the foods area. The judgment of fabric quality has been done by tactile methods for a long time. Binns (1926) has compared trained and untrained persons in the judgment of wool fabric quality using the sense of touch termed the 'softness of handle'. The assessments were related only to the grade of wool and blendings of wool grades. Binns results indicate a striking agreement between the average judgments of the trained and untrained persons. Reed (1969) and Mallon (1980) have assessed the preference or desirability of certain groups of fabrics taking into consideration the various components or physical properties in the fabrics used.

Further developments of sensory evaluation in the textiles area have been the introduction of techniques for assessing the physical characteristics, roughness, compressibility, and flexibility, by Stockbridge and Kenchington (1957), Howorth and Oliver (1958), Dawes and Owen (1971B), and Elder, Fisher, Armstrong and Hutchison (1984A and B). Yet, a complete record of the tactile complex is not obtained. In studies done by Kawabata (1980), the objectivity has been increased by the development of standard scales to be used by textile experts when they assess the fabric hand using professional skills. Although different scales and terminology have been used for different groups of fabric, such as winter suiting, summer suiting and dress weight fabrics, this method has been found to have bias (Kawabata, Mahar, Niwa and Postle, 1981).

The Texture Profile method has been used successfully in the foods area to obtain an accurate description and measurement of the texture complex of food products. In the textiles area, there is not an equivalent method to supply an accurate description and measurement of the tactile complex of textile products. There is a need for further development of sensory evaluation methods based on standardized objective procedures.

The purpose of the present study was to develop and evaluate a method of assessing fabric hand that was based on the principles of the Texture Profile method through use of commonly understood terminology, development of standardized handling techniques and development of interval rating scales using reference fabric samples. The evaluation procedures developed included the following major properties: surface characteristics, compressibility, flexibility, thickness, and weight. The procedures were formulated, during the development of standards and procedures for sensory evaluation.

The first stage included collection of data about words that have been used in previous studies to describe various properties and property levels. The definitions for the properties, descriptive words, and the handling techniques were developed and refined for the sensory evaluation by a sensory panel. Scales with reference standards were also developed for surface texture, surface contour, surface friction, compressibility, flexibility, thickness, and weight.

Following the development of standards and procedures, a panel was trained to use the method and perform a test trial of the method. The test trial was used to examine the reliability of the method. The panel assessed a variety of apparel fabrics that covered a range for each physical property and used interval rating scales to record the results. Using these results, profiles of the fabric hand for the fabric samples were developed by the researcher.

To examine the relation between the sensory and instrumental methods, instrumental property values were obtained and correlated with the corresponding sensory evaluations. The instrumental techniques used were those that had shown in past studies high correlation with sensory assessments.

The study was considered exploratory and the objectives guiding the study were:

1. To develop a sensory method to assess the individual properties of surface texture, surface contour, surface friction, compressibility, flexibility, thickness, and weight, by

   a. Developing definitions of the properties and the descriptive words used in the method,

   b. Developing handling techniques for the sensory evaluation of the properties, and

   c. Developing scales with points of reference for the properties.

2. To determine the reliability of the method in assessing fabric hand, by

   a. Determining the reliability of the panelists to duplicate their findings from one evaluation to another, and

   b. Determining the reliability of the panel to duplicate its findings from one evaluation to another.

3. To determine the correlation between the sensory evaluation and instrumental measurements for surface friction, compressibility, flexibility, thickness and weight by calculating the correlation

coefficient between the sensory evaluation and the corresponding instrumental measurements.

The limitations of the present study were:

1. The selection of the physical properties was limited to the properties which were selected by the researcher.

2. The selection of the instrumental test methods used was limited to those standard test methods previously found to be related to the physical properties assessed during the sensory evaluations.

CHAPTER TWO

LITERATURE REVIEW

The review of literature is divided into sections: concept of hand, sensory evaluation procedures, and correlation of sensory evaluation and instrumental measurements. The review summarizes work which has been done in the area of sensory evaluation of fabric hand. The section on sensory evaluation procedures includes a look at both fabric hand and food texture under the headings: definition of characteristics, manipulation techniques and sensory test methods. In the latter section, the similarities and differences of the procedures that have been developed are emphasized.

Concept of Hand

Fabric Hand Descriptions

The Textile Institute (1975) has defined hand as the sensory evaluation of a textile material obtained from the sense of touch. Yet researchers have frequently described hand according to their research interests. The descriptions used have been:

1. The assessment of like-dislike for fabric hand by the consumer which is influenced by the constructional components of the fabric; by cultural and psychological factors including time, place, season, fashion, personal and racial predilections; and by the end-use of the fabric (e.g., Pierce, 1930; Kaswell, 1953; Paek, 1978),

2. The psychological response resulting from an evaluation or summation of the physical properties of the fabric through the sense of touch (e.g., Kitazawa and Susami, 1968; Reed, 1969; Harada, 1971; Matsuo, Nasu and Saito, 1971; Kawabata, 1980),

3. The sensations felt by the fingers when fabric is manipulated (e.g., Hoffman and Beste, 1951; Owen, 1970/71), and

4. The stimulus produced by the physical properties of the fabric when touched (e.g., Lundgren, 1969; Kobayashi, 1973; Hollies, 1977).

Descriptions of hand have been either too ambiguous to cover all possible end uses or too specific and cover only selected aspects of hand. Therefore, the description often has not been one of hand per se but a description of one or more characteristics related to hand.

Descriptive Words Related to Hand

Since the sensory assessment has been expressed by words and phrases, the ability to make the assessment has been limited by how well the words are understood. The dictionary meaning of words are subject to change as the conditions of use change. The variable relationship between a word and its meaning creates relatively little confusion as long as individuals who communicate with one another have similar associations with the word (Emberger and Hall, 1955).

Paek (1979) and Winakor, Kim and Wolins (1980) indicate that textile experts have a common language for hand expressions such as stiffness, smoothness, fullness and softness. Consumers, on the other hand, describe hand in their own language, which includes fashion and personal influences. General descriptive words, such as balanced, bitey, coarse, cottony, dead, firm, foody, greasy, harsh, hungry, kind, lean, limp, mellow, nervous, papery, rich, rough, scroopy, stiff, thready, tight, warm and well-round, can provide excellent descriptions of fabric hand when they are interpreted in the same manner by the group of people using the words.

Hoffman (1965) has used psychometrics to provide an accurate measure of consumer opinions regarding fabric hand. He has found certain words in the consumer's vocabulary are used exclusively to describe groups of fabrics. For example, words like attractive, smart, pleasing, well-dressed look and good taste have been associated with desired fabrics. But, nondesired fabrics have words like unpleasant, ordinary, annoying, common and boring associated with them.

Brand (1964) has suggested that the most reliable tool for measuring fabric hand is sensory evaluation and words are important for describing the evaluation. Brand has outlined how to use quality words which are associated with fabric hand. In this method, the participants are asked to identify characteristics by simple word pairs whose meanings are easily recognized as opposites. Appropriate word pairs should represent well-understood characteristics that can be related to hand by mathematical analysis. Such word pairs often suggest possible instrumental measurements. While one way to clarify the meanings of the words is to try and define them, Brand suggests that definitions are too confining or ambiguous. But, he suggests guidelines can be followed in selecting words, for example, words should have value content, be technically explicit, and be associated with a physical property.

The method Harada, Saito and Matsuo (1971) used to select words includes similar guidelines to Brand's (1964). Harada, et al. use descriptive terms for hand defined on the basis of measurable properties of fabrics. To accurately and efficiently define the descriptive terms for hand, they suggest that the descriptions must be expressed with as small a number of descriptive words as possible and the meanings of the descriptive words should be instrumentally defined.

Sensory Evaluation Procedures

Definition of Characteristics

Definitions are useful in identifying the characteristics being discussed. When definitions differ between studies, difficulty occurs from uncertainty about whether similar or different characteristic are being studied. In the textiles area, the definitions have varied while in the foods area, the profile methods provide standard definitions of the characteristics. The same definitions are used for each study.

Fabric Hand Characteristics. Table 1 lists the characteristics of fabric hand used in past studies. The researchers have selected different combinations of characteristics as a measure of hand because certain characteristics affect perception of hand for certain fabrics more than others. Kitazawa and Susami (1968) and Matsuo, et al. (1971) explain fabric hand by assessing a physical property corresponding to the various elemental deformations of fabrics. The deformations are bending, shearing, compression, extension and weight.

Table 2 gives a list of the physical properties and the descriptive terms related to fabric hand as published in the American Society for Testing and Materials manual (1982). Researchers have usually defined the properties and terms they use according to their scope of interest. Their definitions may be similar to Table 2 or different. Therefore, the actual meaning of the properties and terms differ

Table 1. Fabric Hand Characteristics Studied in Past Studies.

bodily comfort	skin contact
harshness	softness
roughness	smoothness
compactness	coarseness
thickness	weight
warmth	stiffness
stretchiness	liveliness
friction	compression
fullness	resilience
pliable	crispness
anti-drape	soft-feeling
scrooping feeling	flexibility with soft-feel
flexibility	extension
surface friction	surface contour
thermal character	

Sources: e.g., Bogaty, Hollies and Haris, 1956; Stockbridge and Kenchington, 1957; Howorth and Oliver, 1958; Reed, 1969; Matsuo, et al., 1971; Dawes and Owen, 1971A and B; Jarrelle, 1973; Paek, 1975, 1978 and 1979; Mallon, 1980; Kawabata, 1980.

Table 2. Physical Properties, Associated Explanatory Phrases and Descriptive Terms Related to Fabric Hand

Physical Properties	Explanatory Phrases	Descriptive Terms
flexibility	ease of bending	pliable -- stiff
compressibility	ease of squeezing	soft -- hard
extensibility	ease of stretching	stretchy -- nonstretchy
resilience	ability of recover from deformation	springy -- limp*
density	weight per unit volume**	compact -- open
surface contour	divergence of surface from planeness	rough -- smooth
surface friction	resistance to slipping offered by the surface	harsh -- slippery
thermal character	apparent difference in temperature of the fabric and the skin touching it	cool -- warm

Note: * resilience may be flexural, compressional, extensional or torsional.

** weight per unit volume is based on measurements of thickness and fabric weight.

Source: <u>American Society for Testing and Materials</u> manual (1982) among studies with the result that comparisons are difficult.

Food Textural Characteristics. In the Texture Profile method, the characteristics have been defined. During use, the definitions of the characteristics are the same whenever the profile method is used and do not change because the researchers have different scopes. The definitions for the food textural characteristics have been grouped into mechanical, geometrical and other characteristics. Szczesniak (1963) defines the mechanical characteristics as those manifested by the reaction of the food to stress. They are measured organoleptically by pressures exerted on the teeth, tongue and roof of the mouth during chewing. Mechanical characteristics have five primary parameters:

1) hardness, the force necessary to obtain a given deformation,

2) cohesiveness, the strength of internal bonds making up the body of the product,

3) viscosity, the rate of flow per unit force,

4) elasticity, the rate at which a deformed material goes back to an undeformed condition

after the deforming force is removed, and

5) adhesiveness, the work necessary to overcome attractive forces between the surface of food and the surface of other materials,

and three secondary parameters:

1) brittleness is related to hardness and cohesiveness and is the force with which the material fractures,

2) chewiness is related to hardness, cohesiveness and elasticity and is the energy required to chew solid food to a state ready for swallowing, and

3) gumminess is related to hardness and cohesiveness and is the energy required to disintegrate a semi-solid food to a state ready for swallowing.

Szczesniak (1963) defines the geometrical characteristics of food as the arrangement of the constituents, which are reflected mainly in the appearance of the food product. They are mostly sensed visually but are often sufficiently pronounced to produce oral sensations through the sense of touch and pressure. Geometrical characteristics cannot be divided into clear-cut divisions but into two general groups, which are those related to size and shape of the particles and those related to shape and orientation of the particles. The other characteristics, moisture and fat content, comprise the mouthfeel qualities.

Manipulation Techniques

The way an object is manipulated conveys information to a person. Thus, mechanics of how the person is handling the specimen affects the perception of the fabric. Techniques for handling fabrics have not been extensively examined in past studies. In the Texture Profile method, specific biting and chewing techniques are outlined. A panel is trained to use these techniques to eliminate error that can result from differences in chewing of the food sample.

Fabric Handling Techniques. Table 3 outlines the three kinds of handling instructions given in past studies of fabric hand. These are: consumers handling the fabric freely and in a normal manner, textile experts handling the fabric according to their professional skills, and handling according to instructions given. The majority of investigators have used the first category, allowing the participants (consumers) to handle the fabric samples

Table 3. Fabric Handling Instructions Given in Past Studies.

Instructions	Researchers
participants (consumers) handle the fabric freely and in a normal manner	Howorth and Oliver, 1958; Howorth, 1964; Winakor, et al., 1980; Barker and Scheininger, 1982
participants (experts) handle the fabric according to their professional skills	Gunther, 1952; Kawabata, 1980
participants to follow instructions given, which are:	
a) to use the same hand throughout the experiment and to explore the fabric on the bias with their fingertips	Stockbridge and Kenchington, 1957
b) to lay fabric flat on table and make an assessment by stroking the fabric over the surface	Howorth and Oliver, 1958
c) to stroke the fabric's surface using a light pressure	Dawes and Owen, 1971B
d) to set four fingers on top of a sample, apply light pressure, using same amount of pressure on each sample	Elder, Fisher, Armstrong and Hutchison, 1984A
e) hold lightly between the thumb and forefinger of one hand and bend to form an arc	Elder, Fisher, Armstrong and Hutchison, 1984B

freely and in a normal manner. A large number of these studies are associated with preference. Researchers have reasoned that the participants will reconstruct how they would evaluate the fabrics in an average situation. Consumer assessment for preference of fabric hand is influenced by cultural and psychological factors such as time, place, season, fashion, personal and racial predilections (Kaswell, 1953).

When handling instructions are not given, the way fabrics are handled will vary from person to person and from fabric to fabric. Dawes and Owen (1971A) have found that panelists used different handling techniques when assessing the stiffness of fabrics that ranged from very limp to stiff. They suggested that panelists felt instinctively that limp fabrics could be crumpled without causing creasing and they perceived these fabrics to be so similar that more severe bending was used to distinguish between the limp fabrics.

Precise handling instructions have been given in a few studies (refer to Table 3). The instructions have explained how the person was to feel the fabric and the amount of pressure to use. Studies have shown that the response to the fabric stimuli is influenced by the handling technique. LaMotte (1977) has shown that the sensations of smoothness and roughness as well as the perceptions of the surface pattern are greatly enhanced by movement of the object relative to the surface of the skin. Whether the skin was moved over the surface or the surface was moved over the immobile skin seemed to make no difference in results. According the Dawes and Owen (1971B) different properties of the fabric may be precived when different levels of pressure are used.

Steven and Harris (1962) have examined the scaling of subjective roughness and smoothness using samples of emery cloth. During the study, grit 120 emery cloth was consistently judged rougher than grit 100 even though grit 100 emery cloth is sold as being rougher than grit 120. Under close examination, grit 120 normally has smaller abrasive particles than grit 100, but the two cloths differ in the degree to which the particles appear to be immersed in the adhesive. The particles of grit 120 sit higher on the cloth and thus more of their surface can be felt. The skin catches on the finer particles in a way that is not characteristic of the coarse particles thereby accounting for the higher apparent roughness.

Lederman and Taylor (1972) have studied the perceived roughness of grooved metal plates under conditions of active touch with controlled finger force. The perception of roughness increase as the width of the grooves in the plates increases, as the areas between the grooves decreases, and as the finger force increases. The findings suggest that the roughness of a uniform surface and the contrasts in the roughness of different parts of a patterned surface would be altered by changes in the manner of feeling the surface.

Lederman (1974) did further investigation into the effect of applied force and the rates of hand motion. Results showed a large subject difference in the force applied, with the averages for the subjects ranging from 17 to 27 g. Under the experimental conditions, both controlled and uncontrolled forces appeared to yield similar results for perceived roughness of grooved plates. There appeared, however, to be a trend for the finger force to increase slightly with increases in groove width. According to Lederman, a possible reason for exertion of a greater force is to prevent the skin from catching on the leading edge of areas between the grooves. The assessed roughness at slow to medium rates of hand motion were very similar but at high speed, the assessed roughness decreased slightly. Apparently the fingers passed in and out of a groove less because there was less time to descend into the groove.

Reports in the literature indicate that the fabric mounting and presentation have an influence on the tactile evaluation of fabric. Table 4 gives a summary of the fabric mounting techniques used by researchers. For example, fabric specimens have been mounted on a piece of cardboard or a wooden block, or laid directly on a wooden or other surface. In many studies, only the specimen dimensions are given with no further information about specific preparation technique. Sometimes the specimens have been 'handed to' the panelists and it is assumed that the specimens are free and not mounted in any special manner.

Dawes and Owen (1971B) have made special mention of the surface on which the fabric specimens in their study were evaluated. The surface was composed of two layers of a raised-loop nylon laminate laid on a wooden table. Each layer had an uncompressed thickness of about 1 mm and the loops were upwards.

Table 4. Mounting Techniques of Fabric Specimens Described in Past Studies.

Mounting Technique	Researchers
fabric specimens were mounted	
a) on white cardboard	Jarrelle, 1973
b) by clamping to a wooden block by a metal frame,	Stockbridge and Kenchinton, 1957
c) by simply laying on a wooden surface inside a box or on a table	Howorth and Oliver, 1958; Reed, 1969; Dawes and Owen, 1971B
fabric specimens were not mounted	e.g., Bogaty, et al., 1956; Howorth,1964; AATCC, 1966; Brown, 1970

Table 5. Method of Fabric Specimen Presentation Described in Past Studies

Presentation Method	Researchers
tactile test with samples hidden, referred to as a blind test	e.g., Bogaty, et al., 1956; Howorth and Oliver, 1958; Howorth, 1964; Reed, 1969; Jarrelle, 1973; Paek, 1975, 1978 and 1979; Mallon, 1980; Winakor, et al., 1980; Morris and Prato, 1981; Elder, et al., 1984A and B
tactile test with both visual and audio senses controlled	Stockbridge and Kenchington, 1957
tactile test with samples not hidden	Dawes and Owen, 1971A and B; Kawabata, 1980; Kawabata, Mahar, Niwa and Postle, 1981
tactile and visual tests combined	Jarrelle, 1973; Paek and Mohamed, 1978

The purpose of this surface construction helped to even out small differences in applied pressures between the participants. The backing layers were resilient and did not change in thickness or softness during the tests.

The method of presentation refers to the way the fabric specimen is presented to the panelists. Table 5 lists four types of presentations researchers have used. The most common method has been to have the evaluation done when the samples are hidden behind a screen or placed in a sensory box. This has been referred to as a blind test. In studies on fabric hand, reference has been made to the fact that the results of subjective tests may be strongly influenced by the appearance of the fabrics, even though the persons are attempting to discount the visual effect (Howorth and Oliver, 1958). In addition to the visual effect, Stockbridge, et al. (1957) have controlled the audio effect that may influence the sensory assessment.

Another method is to have the evaluation done with the specimens not hidden from view. In these studies, precautions have been taken to control the influence of the fabric's appearance. For example, Paek and

Mohamed (1978), used fabric specimens with the same colour and very little difference in appearance. They justified the use of touch and sight for these studies because hand assessment using both visual and tactile means is similar to the actual fabric preference process of consumers.

On the other hand, Kawabata (1983) has reasoned that experts know there is a correlation between visual and tactile assessments. In his study, fabric hand was evaluated against standard samples to eliminate the influence of fabric appearance. When standard samples were not used, the visual effect had to be taken into account but for experts the effect was negligible.

Food Evaluation Techniques. In the foods area, more progress has been made in development of techniques that control the influence of the individual. The Texture Profile method employs explicit instructions for the entire evaluation from the initial bite through the masticatory phase to swallowing. The positioning of the food specimen, pressure to use in chewing, location in the mouth, the number of chews and the size of the specimen are specified. These procedures have eliminated personal and psychological influences from the results. The panelists are trained in the techniques prior to the testing sessions.

In the Texture Profile method, the training of the panel is important. To educate the panel, two approaches are used depending on the desired end result. One approach is to train the panel to have the ability to do multiproduct texture evaluations and a second approach is to train the panel to evaluate a specific product.

The training includes an explanation of the basic concepts of texture and the components of the profile method, definitions and evaluation techniques for textural characteristics, and use of the reference scales. Practice, using the techniques and the corresponding reference scales, is employed (Civille and Szczesniak, 1973). During the training sessions, group discussions are encouraged to bring to light any difficulties with the definitions, techniques and reference scales. This process contributes to the training and helps the panel to develop skills and interest in the work.

Sensory Test Methods

There have been several sensory test methods employed for sensory evaluation, for example, single object at a time, paired comparison, ranking, rating, and magnitude estimation. These methods have been used in both the foods and textiles areas but the discussion, in the following section, is focused on the textiles area.

The simplest method is to evaluate a single fabric at a time. Bogaty, et al. (1956) have used this method and found a large variability in the results. The analysis has shown that both the participant and fabric contribute significantly to the total variability. The participant is unable to remember previous fabric samples and cannot use them as references for the next fabric sample. The approach has not been used very often because of the large variability associated with it.

Paired comparison, another procedure used, is based on the simple act of making a choice between two samples (ASTM, 1968; Larmond, 1977). The choice is made on the basis of some specified physical characteristic or property. The results are the relative frequencies of choice of the two samples.

Examples of researchers, who have used paired comparison for fabric testing, are: Stockbridge, et al. (1957), Howorth and Oliver (1958), Howorth (1964), Brown (1970), Paek and Mohamed (1978), and Paek (1979).

The advantages of the paired comparison procedure are: 1) the range of potential application is broadened by its simplicity, and 2) the freedom from depending on the participant's memory. The disadvantages are that: 1) as the number of samples increase, the number of possible comparisons rapidly increase to a point where they cannot be handled in one session due to excess fatigue, and 2) the test method may fail to take advantage of the participant's full range of ability to discriminate. According to Bogaty, et al. (1956) the main difficulties of using paired comparisons are intrusion of other psychological cues, onset of fatigue after four or five pairs, and judgements cannot be readily related to each other when made at different times.

Ranking, a third method used, is considered an extension of the paired comparison method (ASTM, 1968; Larmond, 1977). Ranking methods involve presenting a number of samples to the participant who then orders these according to the degree to which they exhibit some specified characteristic or property. Usually, the participant assigns a preliminary order and then is allowed to check back on the placement of particular samples. The number of samples may vary from three to a maximum limit of about ten. An upper limit is recommended because of the difficulty of considering many stimuli at the same time; more confusion occurs if the fabrics that are being evaluated are extremely similar (Bogaty, et al., 1956). Matsuo, et al. (1971), Dawes and Owen (1971A), Mallon (1980), Winakor, et al. (1980), and Barker and Scheininger (1982) have been some of the researchers who have used ranking.

Rating is a fourth method that is used (ASTM, 1968; Larmond, 1977). The rating method provides the participant with a scale showing several degrees of magnitude (increments) for the specified characteristic or property. The sample(s) are presented and the participant assigns each with a scale value that reflects the amount or intensity of the specified characteristics. The common applications are evaluation of hedonic value for consumer preference; evaluation of people's opinions about the quality of materials; evaluation, in either hedonic or quality terms, of the response to certain characteristics of a product; and evaluation of the degree or intensity of specific characteristics of a material. Examples of researchers who have used rating are: Reed (1969), Dawes and Owen (1971B), Jarrelle (1973), and Kawabata (1980). The types of scales that have been used for rating are graphic scales, verbal scales, numerical scales and scales with reference standards. Depending on the product and characteristic or property being evaluated, scales may vary in length and number of increments.

Reference line scales are used for the Texture Profile method. They consist of a horizontal interval line scale with seven to nine increments marked along the length. Standard reference samples are supplied for each increment to demonstrate the associated magnitude of the physical property. During the training sessions, the standard reference samples may be modified and more suitable references sought if panelists have difficulty with the scales. The actual line scale used by the panelist to record the assessment consists of a horizontal line with anchor points near each end. These are semi-structured with the anchor points labelled with descriptive terms related to the physical property being measured. For example, the hardness scale uses the descriptive terms soft - firm - hard. The panelist makes a vertical line across the line scale at the point that best reflects their perception of the magnitude of the property (Stone, Sidel, Oliver, Woolsey and Singleton, 1974). Difficulties encountered in using scales are a lack of understanding of how to use the scales, of the meaning of the scale values, the lenght of the line scale, and of the physical properties being rated.

The fifth method is magnitude estimation, a procedure used to enable ratio scaling (ASTM, 1968). This method, similar to the rating scale method, is used to assign degrees of magnitude to stimuli on a specified psychological continuum. The difference lies in the way of obtaining the scale. It is developed by the subject rather than given by the researcher. The subject is instructed to conceive the numbering system giving special emphasis to the necessity of using the system as a ratio scale. For example, assigning 10 to a stimulus should mean that it seems ten times as strong as a stimulus which is called 1, half as strong as one which is called 20.

Physical reference samples with predesignated values may be included. The stimuli are presented singly, and subjects assign a number to each. The method has been employed in laboratory experiments to investigate the relation of physical stimulus intensity to perceived magnitude.

Stevens and Harris (1962) point out that the difficulty in using magnitude estimation for characteristics such as smoothness-roughness is that the subjects find the task of judging the reciprocal difficult. For example, if the product is five times as smooth as the reference standard then this should be the opposite of five times as rough as the reference standard. Elder, et al. (1984A and B) have used the magnitude estimation method in assessing the hand of textiles.

Correlation of Sensory Evaluation and Instrumental Measurements

In the previous section, past studies of fabric hand have been examined to look at the progress made or, in some instances, the lack of progress compared to that of the Texture Profile method in the foods area. The focus has been on the sensory evaluation of fabric hand but researchers have also been interested in the correlation of the sensory evaluation with instrumental measurements. Knowledge about the association between the two measurements may, in some cases, allow instrumental measurements to replace sensory evaluation when information is needed rapidly.

Studies have shown that the overall sensation of hand can be divided into individual characteristics that are perceived through manipulating the fabric. These characteristics correspond to physical properties that can be instrumentally measured. The studies can been divided into those that examine the relationship of physical property(ies) with corresponding sensory evaluation, and the interrelationships among fabric elements relating physical properties to fibre, yarn and construction elements.

Relationship of Sensory Evaluation with Corresponding Physical Property(ies)

An association between sensory hand evaluation and physical properties of a fabric may be demonstrated if appropriate physical properties and measurements are chosen (Kitazawa and Susami, 1968). The instrumental measurements studied have been obtained using either standard or author-developed test methods. In Table 6, the studies listed have described the associations between the rank ordering of the sensory evaluation results and the instrumental measurement values. Studies by Pierce (1930), Rose, Graves and Naglik (1976), Brown (1978) and Elder, et al. (1984A and B) have involved one physical property of fabric hand while those of Dreby (1942), Abbott (1951), Dawes and Owen (1971A), Jarrelle (1973), Mallon (1980), and Barker and Scheininger (1982) have investigated several physical properties of fabric hand.

Table 7 lists the studies describing the associations between the ratings of the sensory evaluation results and the instrumental measurement values. Reed (1969), Kawabata and Niwa (1975), and Kawabata (1980) have reported correlations between the subjective assessments and objective measurements. The studies have varied in the subjective experimental procedures used and in the physical properties examined.

Table 6. Rank Correlation of Instrumental Property Measurements with Corresponding Sensory Evaluations Described in Past Studies.

Researcher	Type of Fabrics	Property	Instrumental Measurement Used	Statistical Correlation
Dreby, 1942	cotton percales	pliability	Planoflex	0.70
			Frictionmeter	0.44
			Compressionmeter	0.12
Abbott, 1951	wovens	stiffness	ASTM D 1388, option A	
			bending length	0.56
			flexural rigidity	0.78
			ASTM D 1388, option B	
			bending length	0.63
			flexural rigidity	0.62
			Flexometer	0.70
			Planoflex	0.58
Dawes and Owen, 1971 A and B	wovens	stiffness	bending hysteresis	
			elastic flexural rigidity	0.89
			coercive couple	0.84
			Shirley Stiffness Tester	
			flexural rigidity	0.87
		smoothness	surface-air leakage test	0.90
	raised-loop nylon	stiffness	bending hysteresis	
			elastic flexural rigidity	0.84
			coercive couple	0.28
Jarrelle, 1973	wovens	stiffness/ compression	ASTM D 1388, option A	0.85
			using the Drap-Flex Stiffnes tester	0.87
		friction	Thwing-Albert Handle-O-meter	0.54
		weight	weight	0.94
		thickness	thickness	0.91
Barker and Scheininger, 1982	nonwovens	stiffness	ASTM D 1388, option A	
			bending length	0.75
			flexural rigidity	0.90
		friction	Inclined plane method	
			static friction	0.19
		thickness	ASTM D 1777	0.73
		weight	ASTM D 1910	0.82
Elder, et al., 1984 A and B	woven wool	compression	Instron Tensile tester with compression load cell	0.96
		stiffness	Shirley Cyclic Bending test	
			bending length	0.77
			flexural rigidity	0.88
			BS: 3356, option A	
			bending length	0.85
			flexural rigidity	0.88
	nonwovens	compression	Instron Tensile tester with compression load cell	0.92
		stiffness	BS: 3356, option A	
			bending length	0.99
			flexural rigidity	0.98

Table 7. Pearson's Product-Moment Correlation of Instrumental Property Measurements with Corresponding Sensory Evaluations Described in Past Studies.

Reasearcher	Type of Fabrics	Property	Instrumental Measurement Used	Statistical Correlation
Reed, 1969	suiting fabrics	stiffness	BS: 3356, option A	
			bending length	0.89
			flexural	0.70
		compression	Schiefer's method using the compressometer, percent compression	0.93
		friction	ASTM D 1894-63	
			coefficient of kinetic	-0.18
			coefficient of static frictions	-0.21
Kawabata, 1980	men's winter suiting	stiffness	KES-FB system used for the following measurements	0.93
		smoothness		0.79
		softness/ fullness		0.78
	men's summer suiting	stiffness	KES-FB system used for the following measurements	0.80
		softness/ fullness		0.39
		spread/ anti-drape		0.69

The Relationship of Fabric Characteristics to Physical Properties

Investigators have indicated that the fibre, yarn and fabric constructions, and finishing processes affect physical properties which in turn influence the hand that is perceived. The influences of fibre content have been investigated for fibre blends of wool and synthetic fibres by Bogaty, et al., (1956) and Kitazawa and Susami (1968) and for fibre length by Howorth (1964). The effects of yarn size have been examined by Kobayashi and Suda (1966).

The effects of fabric construction have also been investigated. Barker and Scheininger (1982) have studied nonwovens processed by spunbonded and spunlaced methods that varied as to weight, fibre content and pattern of construction. Kitazawa and Susami (1968) and Mallon (1980) have studied the effects of various types of weaves. Dawes and Owen (1972) have studied the hand of fabric laminates, while Rose and Zeligman (1977) have compared the effects of printed and random coatings of resin on hand of fused laminate. Also, finishing processess have been investigated. Finnimore (1982) indicates finishing processess, such as: chemical pressing, surfactants on wool, selective bleaching of wool, and heat treatment of wool influence hand. Paek (1975) has evaluated effects of finishes applied to produce flame-retardant fabrics for children's sleepwear on hand. Latta, Pensa and Roldan (1974) and Brown (1970) have studied the effects of refurbishing on fabric hand.

The review of literature has outlined the concept of hand showing various descriptions of fabric hand and a lack of uniformity in the use and meaning of descriptive words. The sensory evaluation procedures, in general, have not been defined and developed to the sophisticated levels found in the food Texture Profile method. The results from past studies on hand have lacked the objectivity needed to obtain accurate measurements of hand.

Results from past studies have been useful for indicating consumer preference or desirability of the fabric hand but have not been useful for providing information which textile technologist can use for quality control or product development. The objectives of the present study were to develop standardized procedures for a sensory evaluation method that would increase the objective measurement of hand.

CHAPTER THREE

METHODOLOGY

This was an exploratory study to develop and evaluate a method of assessing hand using commonly understood terminology, standardized handling techniques, and scales with reference standards. Standards and procedures were formulated for the sensory evaluation of the surface characteristics, compressibility, flexibility, thickness and weight. To test the effectiveness of the method, a panel, trained to use the developed procedures, assessed the fabric hand of various apparel fabrics. Instrumental measurements were obtained for the properties and correlations were calculated for the sensory evaluations of surface friction, compressibility, flexibility, thickness and weight, and corresponding instrumental measurements.

Development of Standards and Procedures for Sensory Evaluation

In the development of standards and procedures for sensory evaluation, three stages were used. During the first stage, data about words that have been used in previous studies to describe various apparel fabrics were collected. In the second stage, definitions for the properties, descriptive words associated with property levels and the handling techniques were developed and refined for the sensory evaluation procedures. In the final stage, scales with reference standards were established. The persons involved in the different stages were volunteers who responded to correspondence memos.

Descriptive Words

The purpose of this stage of the study was to collect data about words that had been used in previous studies to describe various apparel fabrics. Participants were gathered to feel a group of 18 apparel fabrics and select the words they would use to describe fabric hand of this variety of fabrics. The group of apparel fabrics used in this stage varied in fibre content; fibre, yarn, and fabric structure; and finish. The participants, a panel of 18 people (16 females and 2 males), were drawn from the departments of Clothing and Textiles, Foods and Nutrition, and Electrical Engineering and were made up of professors, graduate students, and laboratory technicians. Some of the participants had had experience with sensory panels in the foods area.

The list of descriptive words used is given in Table 8. The words selected for the present study were from the list compiled by Vaughn and Kim (1975) corresponding to the physical properties: flexibility, compressibility, thickness, weight and surface characteristics. The panel was asked to feel the group of apparel fabrics and check off the words best describing them. Additional words could be added by participants when desired. The list of descriptive words was used because some panelists were unfamilar with descriptive words used for fabrics. A second session, similar to the first session, was used to check if the fabrics were being effectively described by the words chosen. For this session, the list was condensed to those words used with 75% or more frequency.

Table 8. List of Descriptive Words Given to Panel.

boardy	lumpy
bristly	mushy
bulky	nappy
clumsy	nonresilient
coarse	open
compact	papery
compliant	pliable
crisp	puffy
drapable	resilient
even	rough
firm	scratchy
flexible	sheer
flimsy	silky
full	slippery
furry	smooth
fuzzy	soft
hard	solid
harsh	springy
heavy	spungy
irregular	stiff
lean	supple
level	thick
light	thin
limp	weighty
lively	wooly
loose	

Source: Vaughn and Kim, 1975.

In the third session, participants were again given the shorter list of the frequently used words and asked to describe how the fabric was handled to arrive at their decision about which descriptive words suited the fabric. Words associated with similar handling techniques were assumed to be related to similar properties and were grouped together by the researcher. This process gave an indication of the most common descriptive words the panel used and their associated assessment techniques.

Definitions and Handling Techniques

The purpose of this stage of the study was to develop and refine the definitions for the properties, descriptive words associated with property levels, and the handling techniques. Again, the group of apparel fabrics used varied in fibre content; fibre, yarn, and fabric structure; and finish. Seven female panelists, consisting of professors, graduate students, and laboratory technicans from the departments of Clothing and Textiles, and Foods and Nutrition, formed the panel. Approximately half the panel had had experience with the Texture Profile method in the foods area.

The process used consisted of two steps. In the first step, the researcher directed the panel, using group discussions, to develop definitions for each property and to select suitable descriptive words. The list of frequently used descriptive words was used as the basis for this selection. Then, the panelists were directed to develop a handling technique, using the previously described assessment techniques as the starting point.

In the second step, the panel assessed fabric samples using the developed handling technique in a mock test. The fabric samples were a selection of six specimens of apparel fabric that represented a range of levels for each property. The panelists recorded their scores on line scales anchored near each end with the defined descriptive words that indicated low and high property levels. Reference samples, selected by the researcher according to their instrumental measurement values, were provided to give an indication of the property levels along the line scale.

Analysis of variance was used to examine the performance of the panel. Two factors were studied to give an indication as to the performance of the panel, panelists and fabric samples. The factor, panelists, should not be significantly different if the panelists were giving similar assessments to the fabric samples. The factor, fabric samples, should be significantly different if the panelists were judging a difference in the property levels. When these results were achieved and panelists were comfortable with the reference samples and handling technique, the procedure was kept. The resulting procedures are listed in Table 9 and 10. Table 9 lists the terminology selected and Table 10 lists the handling techniques developed.

This process was completed for flexibility, compressibility, thickness, weight and for each surface characteristic. The surface characteristics were divided into surface texture, surface contour, and surface friction to gain greater information about the hand of the fabric surface. Discussions with the panelists indicated that assessment of the three surface properties was needed to fully measure the fabric hand. Each step in the process took a session. For some physical properties, an additional session was needed. For example, flexibility required two sessions for the first step and each of the three

Table 9. The Terminology Selected for Each of the Properties.

a) Flexibility is the amount of stiffness in the fabric sample. The stiffness is measured by the ease with which the fabric deforms or the resistance the fabric offers to deformation.

stiff--the fabric sample resists the deformation, and
limp--the fabric sample does not resists the deformation.

b) Compressibility is the ability for the fabric to reduce its thickness when compressed or squeezed.

compressible--the fabric sample decreases in thickness when pressure is applied, the fabric sample `gives' easily when pressed, soft, and
non-compressible--the fabric sample does not reduce in thickness when pressure is applied, there is no `give' to the fabric when pressed, hard.

c) Weight is the heaviness of the fabric sample of the weight of the fabric sample.

heavy--the fabric sample has a large weight, and
light--the fabric sample has a small weight.

d) Thickness is the distance between the upper and lower surfaces of the fabric sample that the finger and thumb feels.

thick--the distance between the finger and thumb is great, and
thin--the distance between the finger and thumb is small.

e) Surface Friction is when the hand is made to slide over the fabric sample, the hand tends to stick, there is a resistance and force is required to keep the hand moving. The magnitude of this force indicates the level of friction between the hand and fabric surface.

rough--the hand sticks to the surface of the fabric sample, which offers resistance and force is required to keep the hand sliding, and
smooth--the hand does not stick to the surface of the fabric sample, which offers little to no resistance and a low amount of force is required to keep the hand sliding.

f) Surface Contour is the amount the fabriec's surface deviates from a plane.

uneven/bumpy--the fabric's surface follows a wavy line and deviates from planeness, and
even/flat--the fabric's surface follows a straight line and does not deviate from planeness.

g) Surface Texture is the amount of fibre ends protruding from the surface of the fabric sample.

fuzzy--the fabric's surface has protruding ends, and
nonfuzzy--the fabric's surface does not have protruding ends.

Table 10. The Handling Techniques for Each of the Properties.

a) For flexibility, the fabric sample is placed on the table. Gently fold the fabric sample in half across the warp yarns. The face of the fabric will be on the inside. Press down gently and slowly with the top portion of the fingers on the fold of the fabric, do not crease the fabric. Make the evaluation when the fingers are pressing down on the fabric and not when they are coming up.

b) For compressibility, the fabric sample is placed flat on the table. Using the full length of the fingers, press down slowly on the fabric. The amount of pressure added is enough to displace a top loading balance by 50 grams.

c) For thickness, the fabric sample is held between the finger and thumb along the edge. Moving the thumb gently over the edge of the fabric sample to evaluate the thickness. Gently refers to a slight pressure being added by the thumb as it moves over the fabric edge.

d) For weight, the entire fabric sample is held in the palm of the hand and move hand slightly up and down to feel the weight. There should be little to no overhang of the fabric sample.

e) For surface friction, the fabric sample is placed flat on the table. Using the top portion of the fingers, graze the surface with a little pressure, in the warp and filling directions. Note largest amount of resistance offered to the fingers by the fabric surface.

f) For surface contour, the fabric sample is placed flat on the table. Using the whole length of the fingers graze the surface with very little pressure, in the warp and filling directions. Note the largest amount of deviation the surface has from a straight line.

g) For surface texture, the fabric sample is placed flat on the table. Using the whole length of the fingers, graze the surface with very little pressure, in the warp and filling directions. Note the largest amount of fuzziness the surface has.

surface characteristics each required two sessions for the second step.

Scales with Reference Standards

The purpose of this stage of the study was to establish scales with reference standards. The same panel participated in this stage and the same group of apparel fabrics were used.

Initially, the reference standards were selected for three points of the line scale by the researcher using instrumental measurement values. These were labelled R_1, R_2, and R_3. The standards represented the anchor points near the low and high ends of the line scale (R_1 and R_3, respectively) and the midpoint (R_2) for a particular property. Other property differences were kept to a minimum to reduce their influence. Using the appropriate handling techniques for a property, the panel evaluated sets of fabrics until agreement was reached for the final set of reference standards.

To do the evaluation, the panel was asked to record the assessment of each fabric sample from the set on the line scale. The desired outcome was for the panelists to place the fabric samples used for

R_1, the lower range of the scale; R_2, the middle range; and R_3, the upper range of the scale; at or near their respective levels on the scale. If this was not the case of if there was disagreement as to the placement of a fabric sample(s), the fabric sample(s) was replaced with an alternative sample with an equivalent instrumental measurement until the panel was comfortable that the reference standards represented respective points on the scale. To complete this process, eight sessions were required. Tables 11 and 12 describe the reference standards used for the scales.

Test Trial of the Evaluation Method for Fabric Hand

Following the development of the standards and procedures, the relibility of the evaluation method was examined. This section outlines the testing components used for the test trial.

Fabric Preparation and Presentation

Description of the Fabrics. For the study, 14 fabrics were selected from the files of the Department

Table 11. Instrumental Property Measurements for the Reference Samples

Physical Property	Measurement Used	R_1 (low)	R_2	R_3 (high)
surface friction[1]	coefficient of static friction (g)	0.37	1.34	2.15
compressibility	compression (mm)	0.04	0.28	1.06
flexibility	flexural rigidity (mg/m^2)	80.5	722.2	1707.8
thickness	thickness (mm)	0.13	2.83	6.02
weight	weight (g/m^2)	47	260	457

Note: [1] the instrumental measurement values for surface friction was used only for the sensory characteristic of surface friction. There were no appropriate corresponding instrumental measurements for the characteristics of surface texture and surface contour indicated in past studies.

Table 12. Fibre Content and Form Characteristics of the Reference Samples

Physical Property	Reference Standards R_1	R_2	R_3
Surface Texture			
fibre content	polyester	wool	wool
fibre structure	filament	staple	staple
yarn structure	simple	simple	simple
fabric structure	plain weave	twill weave	plain weave
fabric count	46 x 36	20 x 20	5 x 5
Surface Contour			
fibre content	polyester	polyester	polyester
fibre structure	filament	filament	filament
yarn structure	simple	simple	simple
fabric structure	plain weave	figure weave with plain and satin	jacquard double knit
fabric count	46 x 36	26 x 20	14 x 18
Surface Friction			
fibre content	polyester	silk	polyester
fibre structure	filament	staple	filament
yarn structure	simple	simple	simple and textured
fabric structure	plain weave	plain weave	jacquard double knit
fabric count	46 x 36	26 x 24	14 x 18
Compressibility			
fibre content	polyester	cotton	polyester
fibre structure	filament	staple	staple
yarn structure	simple	simple	--
fabric structure	plain weave	pile weave	nonwoven
fabric count	46 x 36	16 x 20	--
Flexibility			
fibre content	silk	polyester	cotton
fibre structure	filament	staple	staple
yarn structure	simple	simple	simple
fabric structure	plain weave	plain weave	plain weave
fabric count	64 x 42	20 x 18	32 x 30
Thickness			
fibre content	nylon	wool	polyester
fibre structure	filament	staple	staple
yarn structure	simple	simple	--
fabric structure	plain weave	twill weave	nonwoven
fabric count	44 x 37	21 x 16	--
Weight			
fibre content	polyester	wool	wool, nylon
fibre structure	filament	staple	staple
yarn structure	simple	simple	--
fabric structure	plain weave	twill weave	nonwoven
fabric count	46 x 36	28 x 28	--

of Clothing and Textiles to represent the range of apparel fabrics used in womenswear, menswear and sportswear. As the study was exploratory, the selection included fabrics covering a wide range of each physical property related to hand. A variety of fibre content, yarn and weave structures, and finishes were included. The fabric used are described in Table 13.

Preparation and Presentation of Fabric Specimens for Sensory and Instrumental Testing. The specimens for the sensory evaluation, 150 x 150 mm in size, were cut from each fabric. The fabric specimens used for the physical property of weight, were folded in half then in thirds and hand stitched through the centre with matching thread to reduce the size of the sample to fit into the palm of the hand. The fabric samples were used in the as-received condition after slight pressing to remove wrinkles. Each fabric specimen was coded with a three-digit number from a table of random numbers.

Presentation of the samples was done in a manner that allowed the person to manipulate the fabric sample according to the specified handling techniques. Before the panelists arrived for the

Table 13. Fibre Content and Form Characteristics of Samples Used to Test the Evaluation Procedures.

Fabric Sample A:
fibre content: wool, acrylic
fibre structure: staple
yarn structure: simple
fabric structure: twill weave
fabric count: 10 x 8

Fabric Sample B:
fibre content: linen, polyester, rayon
fibre structure: staple
yarn structure: simple, novelty
fabric structure: plain weave
fabric count: 16 x 15

Fabric Sample C:
fibre content: polyester
fibre structure: filament
yarn structure: simple, textured
fabric structure: jacquard knit
fabric count: 19 x 17

Fabric Sample D:
fibre content: wool, polyester, acrylic
fibre structure: staple
yarn structure: simple
fabric structure: twill weave
fabric count: 18 x 13

Fabric Sample E:
fibre content: polyester
fibre structure: filament
yarn structure: simple, textured
fabric structure: jacquard double knit
fabric count: 13 x 10

Fabric Sample F:
fibre content: linen, polyester
fibre structure: staple
yarn structure: simple, novelty
fabric structure: plain weave
fabric count: 17 x 12

Fabric Sample G:
fibre content: wool, polyester, acrylic
fibre structure: staple
yarn structure: simple
fabric structure: jersey
fabric count: 5 x 5

Fabric Sample H:
fibre content: nylon
fibre structure: filament
yarn structure: simple
fabric structure: jersey knit
fabric count: 22 x 18

Fabric Sample I:
fibre content: wool, nylon, acrylic*
fibre structure: staple, filament*
yarn structure: simple
fabric structure: plain weave, tricot knit*
fabric count: 12 x 10

Fabric Sample J:
fibre content: wool, nylon
fibre structure: staple
yarn structure: simple
fabric structure: plain weave
fabric count: 12 x 10

Fabric Sample K:
fibre content: wool, polyester, acrylic, rayon
fibre structure: staple
yarn structure: novelty
fabric structure: rib knit
fabric count: 4 x 4

Fabric Sample L:
fibre content: linen, polyester, acrylic, rayon
fibre structure: staple, filament
yarn structure: simple, novelty
fabric structure: crepe
fabric count: 32 x 30

Fabric Sample M:
fibre content: wool
fibre structure: staple
yarn structure: simple, novelty
fabric structure: twill weave
fabric count: 7 x 9

Fabric Sample N:
fibre content: silk
fibre structure: staple
yarn structure: simple
fabric structure: plain weave
fabric count: 26 x 17

Note: * backing fabric.

sensory evaluation sessions, four or five fabric specimens were placed in a sensory evaluation booth with a copy of the ballot and the three reference standards. The booths were designed to eliminate influences from the surroundings, reducing sources of error. The individual booths were screened from other panelists in a temperature controlled room. The only lighting in the room was a single red light over the individual booths to mask the appearance of the specimens but sufficient light was available to read the ballot.

Fabric specimens and reference standards were replaced after eight panelists did the sensory evaluation except for the fabric samples used for the sensory assessment of flexibility which were replaced after four panelists completed the sensory evaluations. This procedure was adopted to eliminate error due to alteration of fabric hand by manipulation during the testing.

The specimens for the instrumental measurements were cut from each of the fourteen fabrics according to the directions stated in the standard test methods that were chosen to represent the sensory evaluation methods for the physical properties. Table 14 lists

Table 14. Instrumental Test Methods and Measurements.

Physical Property	Test Method Used	Measurement Obtained
surface friction	Coefficients of Friction of plastic film, ASTM D 1894-64, method B	coefficient of static friction coefficient of kinetic friction (g)
Compress-ibility	Compression test by Schiefer (1933)	mean difference in thickness, increasing from 0.7-14.0 kPa (mm)
flex-ibility	Determination of Stiffness of Cloth, Cantilever test, BS: 3356-1969	flexural rigidity (mg/m^2)
thickness	Fabric Thickness CAN2-4.2-M77, method 37-1977	thickness (mm)
weight	Mass of Fabrics, CAN2-4.2-M77, method 5.A-1977	weight (g/m^2)

the standard test methods used for the instrumental measurements. All fabric samples were stored and tested in standard atmospheric conditions with temperature at 20±2°C and relative humidity at 65±2%.

Sensory Evaluation

The various apparel fabrics were evaluated for each property; surface characteristics (surface texture, surface contour and surface friction), compressibility, flexibility, thickness and weight. The properties were evaluated using the procedures developed to assess fabric hand.

Selection of the Panel. The panel was drawn from the departments of Clothing and Textiles, and Foods and Nutrition and was made up of professors, graduate students, and laboratory technicians. A correspondence memo was circulated to ask for persons to participate in the panel. The selection was limited to eight female persons able to participate in both training and testing sessions. Of the eight persons, four were from each of the above mentioned departments. Three persons had taken part in some of the panels in the development section, and approximately half of the panel had experiance with the Texture Profile method in the foods area.

Training of the Panel. The training of the panel was very important; the panel was introduced to all concepts involved in the sensory evaluation of fabric hand. The training procedure followed closely the Texture Profile method of training to evaluate by specific parameters (Civille and Szczesniak, 1973). The procedures for training of the panel were:

1. A short explanation of the concept of fabric hand and review of past studies was part of the training to act as an orientation to the study and topic, fabric hand. This explanation is given in Appendix 1. Any questions that arose concerning the study and concepts were clarified.

2. A brief explanation of the method used was part of the training to outline the general procedures. Outlines for the following training and actual testing sessions were detailed and explained. This explanation is given in Appendix 2.

3. An explanation of the sensory definitions for the seven properties as listed in Table 9 was part of the training.

4. An explanation of the handling techniques for evaluation of the physical properties was part of the

training. The panelists were asked to use their dominant hand for all the evaluations (refer to Table 10). The other hand was used as necessary for positioning. Four or five fabric specimens were grouped for the evaluations in the sensory booths.

5. A explanation of the evaluation of the physical properties was part of the training. The evaluation of the physical properties was made using the reference line scales, each of the three points was represented by a selected fabric sample. A reference line scale was designed for each physical property to provide a defined, quantitative method of assessing each hand characteristic. As shown in Table 11, each scale encompassed the range of intensity for the physical property, from low to high levels. When the panelists did not agree with the reference standards, they were replaced during the training sessions.

6. A practice exercise using techniques described in the next section was part of the training. The last part of the training was a practice run of the method. Any remaining difficulties or misunderstandings of the evaluation method were clarified before proceeding into the testing

sessions. Appendix 3 gives examples of the ballots used by the panel to record their results.

At the end of the twelve training sessions, the panel was familiar with the definitions of the properties, the descriptive words, the handling techniques, and scales. The trained panel proceeded to evaluate the group of apparel fabrics according to the method of evaluation outlined in the following section.

Method of Evaluation. Upon entering the laboratory, the panelists were asked to assess the fabric specimens in the sensory booth according to the standardized method. Prior to these assessments, the participants were asked to wash their hands to remove any dirt and oil that might interfere with their evaluation. Secondly, they were asked to use the same hand throughout the evaluation sessions. For certain handling techniques, the panelists needed to use their second hand to position the fabric specimen. When the second hand was used, this procedure was used for all the fabric specimens.

When the panelists entered the sensory booths, they were asked to review the terminology and handling technique for the physical property being evaluated during that session. The three reference standards were present enabling the panelists to go back to them to associate a defined property level with each point on the reference scale. After reviewing the reference samples, the panelists were to assess the fabric specimens in the sensory booth in the order indicated on the evaluation ballot and to record their results on the line scale.

The fourteen fabric samples were evaluated for one physical property at each session. The decision to evaluate one physical property for each session was made to eliminate a source of error. The panelists, if given one fabric sample and asked to evaluate all physical properties, may not have been able to switch between the physical properties without error. Seven sessions were needed to complete the assessment of one replication of the physical properties. Two replications were made for each physical property. The second replication was started one week after all properties of the first replication had been completed.

For a session, three sensory booths were used with five fabric samples in the first two booths and four in the last booth. The fabric samples were assigned to the booths so that there was a range of the property intensities in each fabric sample group. The fabric sample groups assigned to the booths were different for the two replications. The order in which the fabric samples were evaluated was randomized within each booth in order to have the fabric samples evaluated in different sequences.

The order in which the physical properties were evaluated was: surface texture, surface contour, surface friction, compressiblity, flexibility, thickness and weight. By using this order, the amount of manipulation of the fabric specimen was increased at each session. First the surface characteristics and the compression of the fabric specimens were rated. For these evaluations, the hand was placed on the surface of the fabric specimens as they were lying on the table. Second the flexibility and the thickness of the fabric specimens were rated. The fabric specimens had to be picked up and manipulated for these properties. For last physical property, weight, the fabric specimens were placed entirely in the panelist's hand. By gradually increasing the manipulation of the specimens in this way, errors that might arise because of influence of the past sessions were reduced.

For each property, the scales were measured by the researcher to obtain numerical values. The values were transformed according to the method of Stone, et al. (1974) to ratings by measuring the distance of the participants' vertical marks from the left end of the lines in units of 0.25 cm.

Instrumental Measurements

The instrumental measurements were obtained using existing standard test methods. The test methods used were ones that had shown a high correlation between the sensory evaluation and the instrumental measurement in previous studies.

Flexibility. The standard test method used was the Method for the Determination of the Stiffness of Cloth, Cantilever test, BS: 3356-1969. As stated, rectangular specimens were projected over the edge of a horizontal surface until, under their own weight, the tips of the specimens made an angle of 41.5 degree with the horizontal.

Bending lenght and flexural rigidity were used for the flexibility measurement. The warp direction only was tested to correspond with the direction tested in the sensory evaluation. The mean of five specimens was calculated for each fabric sample.

Compressibility. The test method chosen was that developed by Schiefer (1933). A Frazier Compressometer was used to determine the compressibility of fabrics. Fabrics were subjected to a series of increasing pressures between the two parallel surfaces of the Compressometer. The perpendicular distance of separation was taken as the thickness. Measurements were taken using 25-mm-diameter anvil at pressures of 0.7, 7.0, and 14.0 kPa. The pressure of 7.0 kPa was used as an intermediate pressure to ensure a gradual increase in pressure. The measurement calculated was the mean difference in thickness when the pressure was increased from 0.7 to 14.0 kPa, expressed in mm.

Thickness. The standard test method Fabric Thickness, CAN2-4.2-M77, method 37-1977 was used. Fabrics were subjected to compression, using the Compressometer, between two parallel plane surfaces whose perpandicular separation was taken to be the thickness of the fabric. A 25-mm-diameter anvil was employed at the pressure of 0.7 kPa. The thickness was expressed in mm.

Weight. The standard test method Mass of Fabrics, CAN2-4.2-M77, method 5.A-1977 was employed. Fabric weight was calculated from the weight of a sample with a known area. The weight was expressed as g/m^2.

Surface Friction. The test method chosen was the standard test method for Coefficients of Friction of Plastic Film, ASTM: D 1894-64 method B. The test involved a fabric-wrapped metal sled being pulled across the same fabric mounted on a horizontal platform. The sled was pulled at a constant rate using an Instron tensile tester. The following measurements were calculated:

1) static coefficient of friction (μs) is μs = A/B, where: A = initial load required to move the fabric wrapped sled in g and B = gross sled weight, and

2) kinetic coefficient of friction (μk) is μk = C/B, where: C = mean force during last 7.62 cm of sliding in g.

Analysis of Data

The analysis of the data was done in two parts. The first part was an evaluation of the reliability of the developed method by looking at individual panelist and overall panel reliability. The reliability of the individual panelists was examined by calculating analysis of variance dividing the total variance into two factors, fabric samples and replications (Stone, et al., 1974). Graphs were constructed for qualitative analysis of the effects between panelists, fabric samples and replications.

The overall reliability for the panel was also analyzed by analysis of variance. The total variance was subdivided into three factors: panelists, fabric samples, and replications, and two interactions: panelists by fabric samples, and panelists by replications. The interaction, fabric samples by replications was not examined because the fabric samples were the same for each replication. Further, Tukey's test was used to determine which fabric samples gave significantly different measurements (Steel and Torrie, 1980). The Statistical Analysis System package (1982) was used.

The second part of the analysis was calculation and study of the correlations between the sensory evaluation scores and instrumental measurements. The Pearson product-moment correlation coefficient was used to measure the intensity of association between the means of the sensory scores and instrumental measurements (Steel and Torrie, 1980). The Statistical Analysis System package (1982) was used.

The significance of the factors used for the analysis of variance and correlation coefficient of the regression was determined using the probability levels. The 'PR > F', the significance probability value associated with the F value, was used to judge whether the F values were significantly different. Values were considered significant if $P < 0.05$.

CHAPTER FOUR

RESULTS and DISCUSSION

The following chapter is divided into three sections: analysis of sensory evaluation, correlation of sensory evaluation with instrumental measurement data, and fabric hand profiles for each fabric sample. The first section, analysis of sensory evaluation, examines the objectives: 1. To develop a sensory method to assess the individual properties of surface texture, surface contour, surface friction, compressibility, friction, thickness, and weight; and 2. To determine the reliability of the method in assessing fabric hand. The second section, correlation of sensory evaluation with instrumental measurements, examines the objective: 3. To determine the relation between the sensory evaluation and instrumental measurements for surface friction, compressibility, flexibility, thickness, and weight.

To determine the reliability of the method, the reliabilities of the panelists and panel were studied. The individual panelist reliability was determined first by examining the analysis of variance for each panelists. Two factors were studied, fabric samples and replications. To have reliability for a sensory measure of hand, the factor, fabric samples, should be significantly different if the fabrics are different and the factor, replications, should not be significantly different. These results would indicate that the fabric samples were assessed as being different and the replications as being similar. Since the fabric samples had different intensities of the properties, the factor, fabric samples, was excepted to be significantly different.

Figures, illustrating the mean scores of panelists and the relation between the mean scores of the panelists and overall mean score of the panel, were prepared and examined. These plots present the mean scores of each panelist for each fabric sample. The spread of values indicates the variation among the panelists in assessing the magnitude of the property. The overall mean score for each fabric sample together with the standard deviation is shown beside the panelist mean scores. These plots show the nature of the variation in the panelists' mean scores relative to the overall mean scores.

Figures, showing the differences between the replications, were also prepared and studied. These plots illustrate the differences between replications one and two for each panelist for each fabric sample and show the spread of differences for each panelist. The differences between the replications were calculated by subtracting the score for replication two from the score for replication one. If the scores for replications one and two were the same, the difference is zero and the plotted value is located on the zero axis (represented by a dotted line on the graphs). The greater the difference between the replications, the further the difference from the zero axis. When the value for the difference are above the zero axis, this indicates that the score for replication one was larger than the score for replication two. In the opposite situation, if the score for replication one was smaller than for replication two, the values fall below the zero axis.

In the plots for panelist mean scores and for the differences between replications, a number of observations are hidden. The observations are hidden because two or more mean scores or differences have similar values. The first panelist mean score or difference value is printed while the subsequent values are not printed. The number of values not printed are indicated in the lower left-hand corner of the plot as observations hidden.

Scores of panelists that lacked reliability because either 1) the factor, fabric samples, in the analysis of individual panelist was nonsignificant indicating failure to distinguish fabrics as being different or 2) the factor, replications, was significantly different indicating failure of replications one and two to be similar, were eliminated from the data prior to the calculation of panel reliability. This strategy is reasonable since, in practice, a larger number of persons would be trained and the persons lacking reliability would then be eliminated before the final panel was selected. When a panelist was eliminated, this occurred only for the property being analyzed at the time.

The panel reliability was examined by analysis of variance. Factors considered were panelists, fabric samples, replications, and the interactions -- panelists by fabric samples and panelists by replications. Tukey's test was employed to determine which fabric sample scores could be considered significantly different and which could be considered similar.

In the second section, correlations between sensory evaluation and instrumental measurement data are examined. To measure the intensity of association, the Pearson product-moment correlation coefficient was used. When a good fit to the association was not obtained various transformations, such as the logarithm of the instrumental measurement values, logarithm of the sensory scores, logarithm of both the sensory scores and instrumental measurement values, square of instrumental measurement values; were calculated until a good correlation was reached. These correlations were studied to determine if the instrumental measurement values for the physical properties could replace the panel results.

In the last section, the profiles for the hand of the fabric samples are presented. These profiles are constructed using bar graphs. The bars represent the magnitude of each property mean score.

Analysis of Sensory Evaluation

The sensory data collected during the test trial are listed in Appendix 4. The univariate statistics for each property are given in Appendix 5.

Surface Texture

The characteristic, surface texture, was judged for each fabric sample by assessing the amount of fibre ends protruding from the surface according to the procedure drawn up during the development of standards and procedures section. Three reference samples were used to demonstrate the increase in surface texture from nonfuzzy (the surface did not have protruding ends) to fuzzy (the surface had protruding ends). The handling technique used to determine the amount of fibre ends protruding from the surface was by grazing the surface with the whole length of the fingers, applying very little pressure.

The individual panelist reliability was studied for the surface texture evaluation and the analysis of variance is presented in Table 15. Apart from Panelist B, each panelist had scores for fabric samples that were significantly different and for replications that were not significantly different. Scores for Panelist B were not significantly different for the factor, fabric samples, indicating a similarity in the scores for the fabric samples.

Table 15. Analysis of Variance for Surface Texture Scores of Individual Panelists.

Panelist	Fabric Samples F value	Fabric Samples (PR < F)	Replications F value	Replications (PR < F)
A	8.90	(0.0002)	3.04	(0.1049)
B	1.70	(0.1766)[NS]	6.34	(0.0257)*
C	20.09	(0.0001)	2.97	(0.1083)
D	4.37	(0.0061)	0.81	(0.3851)
E	5.98	(0.0014)	0.11	(0.7429)
F	5.66	(0.0018)	1.01	(0.3323)
G	10.38	(0.0001)	0.39	(0.5424)
H	11.61	(0.0001)	0.46	(0.5091)

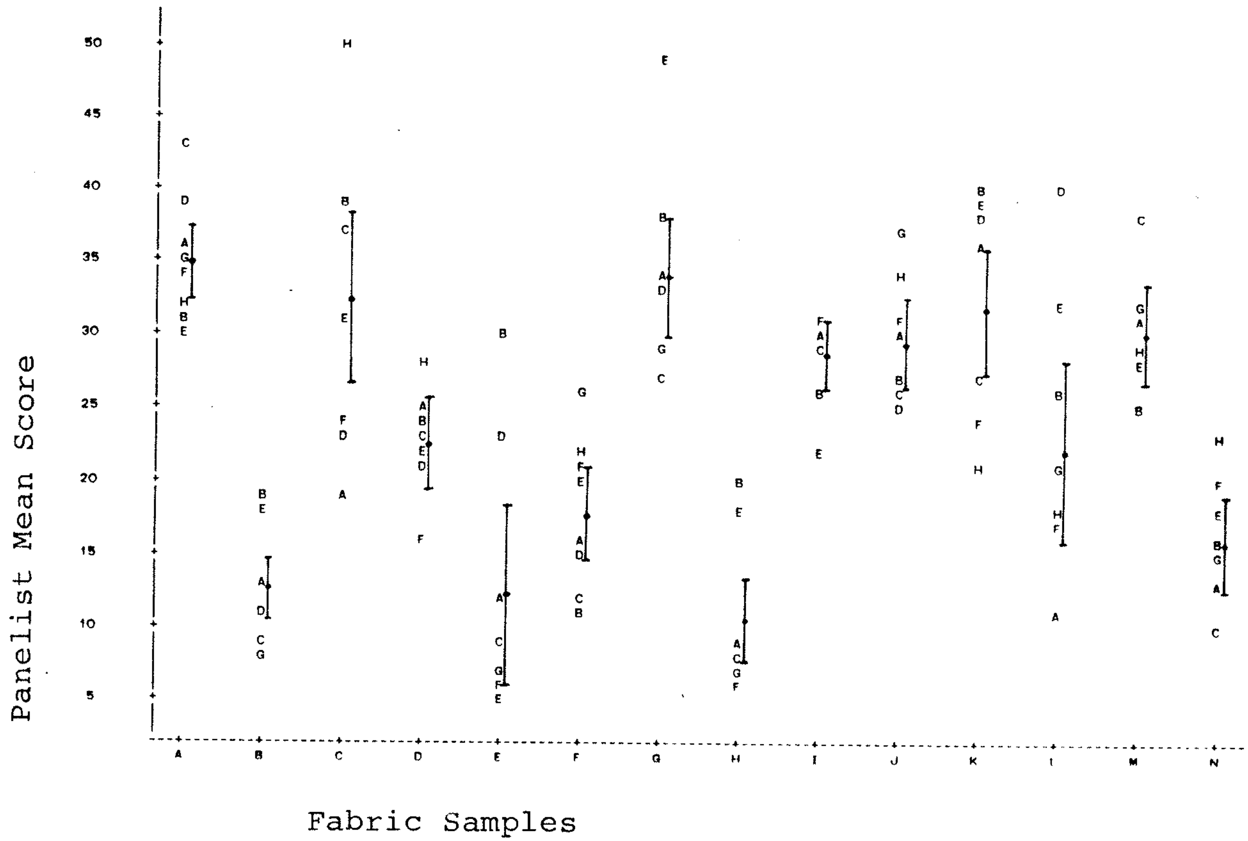
Note: [NS] F value was not significantly different at the 0.05 level.

* F value was significantly different at the 0.05 level.

Results for Panelist B also were significantly different for the factor, replications, indicating that Panelist B was not duplicating the assessment of surface texture.

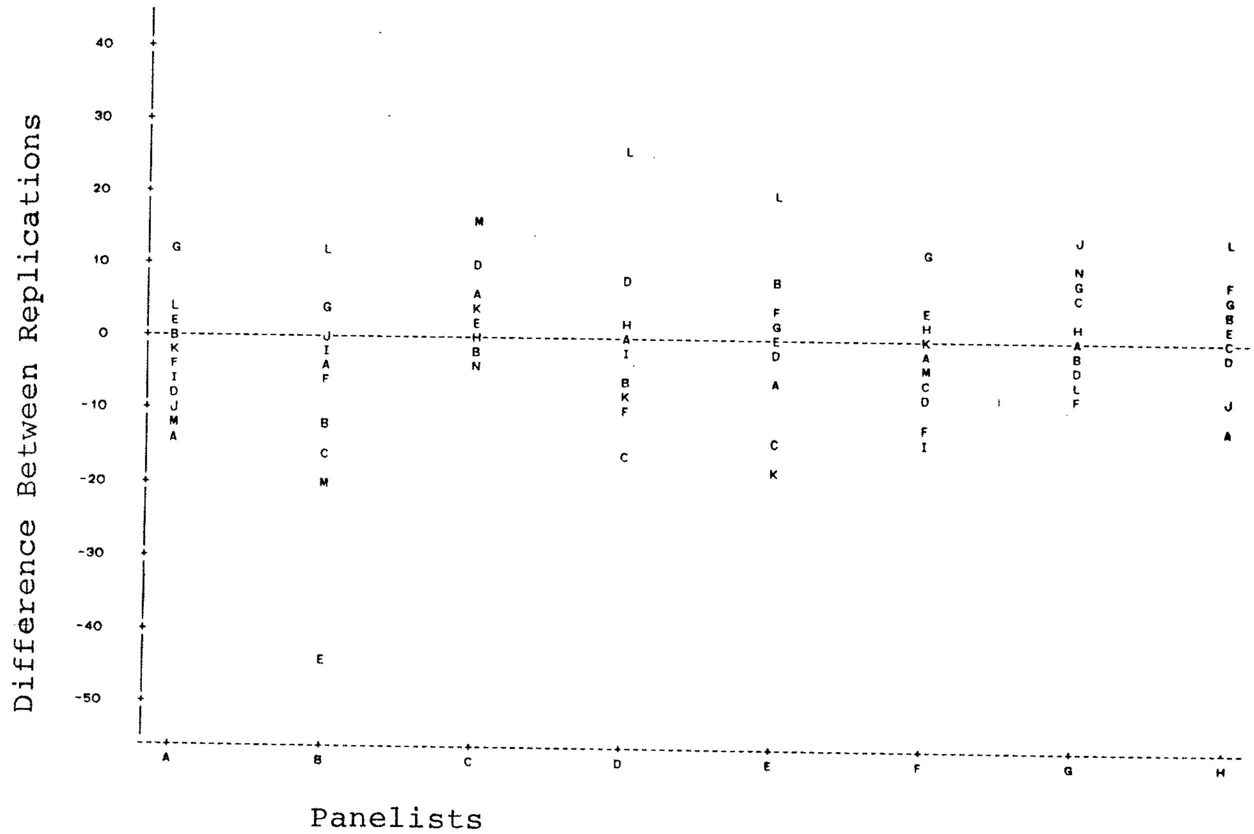
Figure 1 presents the mean scores of each panelists for each fabric sample, the spread of values indicates the variation among the panelists in assessing the magnitude of fuzziness. The mean scores for Panelist B were, in many cases, different from the panel mean scores for this property. For example, scores for fabric samples A, C, G, K, and M, given by Panelist B varied by at least plus or minus one standard deviation from the overall mean score and scores for fabric samples B, E, F, and H, varied by at least plus or minus two standard deviations.

The differences between replications one and two of each panelist for each fabric sample are listed in Appendix 6. Figure 2 illustrates these differences and shows the spread of differences for each panelist. Observation of this Figure shows that Panelist B, whose results for the replications were significantly different, had a greater spread of differences than that of other panelists, especially for fabric sample E. The replication scores for the



Note: 18 observations hidden

Figure 1. Plot Showing the Mean Surface Textue Scores of Each Panelist for Each Fabric Sample.



Note: 36 observations hidden

Figure 2. Plot Showing the Surface Texture Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

remaining panelists were found not significantly different for the assessment of fuzziness.

Because scores of Panelist B lacked reliability, the analysis of variance given in Table 16 for the surface texture results was calculated eliminating Panelist B. In this analysis, a significant F value for fabric samples gives an indication that the fabric samples were distinguished as having different levels of fibre ends protruding from the surface. A nonsignificant F value for panelists would indicate that panelists had similar assessment scores and would suggest panel reliability. Likewise, nonsignificant F values for replications would indicate agreement between replications and provide another indication of reliability.

The interaction was not significant for panelists by replications. The significant interaction between panelists and fabric samples indicated the panelists differed in the way they assessed the protruding fibre ends, depending on the fabric sample. (Refer to Table 16.) Figure 1 shows that certain fabric samples had a wide range of scores. In some cases, scores for one panelist are found at the high end of the range of scores, while in other cases, scores for that panelist

Table 16. Analysis of Variance for Surface Texture Scores of the Panel.

Source	DF	ANOVA SS	F value	PR < F
panelists[1]	6	366.93	2.08	0.0623
fabric samples	13	15245.09	39.96	0.0001*
replications	1	14.88	0.51	0.4803
panelists by fabric samples	78	5908.79	2.58	0.0001*
panel by replications	6	199.00	1.13	0.3534
error	91	2670.88		
total	195	24405.55		

Note: [1] Scores of Panelist B were eliminated because of lack of reliability.

* F value was significantly different at the 0.05 level.

are located at the low end of the range -- demonstrating some interaction.

Observation of the fabrics that were evaluated indicated surface factors that would evoke different perceptions. A few of these will be described. Fabric sample C, an uncut corduroy-type filling pile knit, was made with a texturized pile yarns. When evaluating this sample, some panelists may have assessed the individual filament loops that separated out from the texturized pile yarn as fibre ends while others did not evaluate them as separate fibre ends. Fabric sample L, a novelty yarn fabric, had slub and boucle yarns inserted in the filling direction at intervals. Either the individual filament loops from the boucle yarns and/or the fibre ends from the slub yarns may have been perceived. Thus, making a judgment about the magnitude of protruding fibre ends from these yarns in relation to the remaining portion of fabric that had fewer protruding fibre ends may have been difficult. The novelty yarns, used in the construction of fabrics K and F, allowed fibre ends to protrude. Due to the irregular occurrence of the novelty yarns, panelists probably varied in the amount of fuzziness perceived.

Further analysis with Tukey's test was done to determine which fabrics were significantly different and which were perceived to be similar. The results, from fuzzy to nonfuzzy, were:

A G M C K J I D L F N B E H

Visual observation of the ordering shows common factors within the groupings. The first and second groupings of fabric samples, A, G, M, C, K, J; and G, M, C, K, J, I; have some similar structural details. In the groupings, the spun yarns had a low to medium amount of twist which allowed more fibre ends to protrude. In some, the twill weave or knit structure had long yarn lengths on the surface increasing the amount of protruding fibre ends. The third, fourth and fifth groupings, I, D, L; D, L, F, N; and F, N, B; were mainly plain weave fabrics composed of spun yarns with a medium amount of twist. The last grouping, N, B, E, H, was composed of fabrics constructed with spun yarns without a lot of fuzziness or with multifilament yarns with little to no twist.

Surface Contour

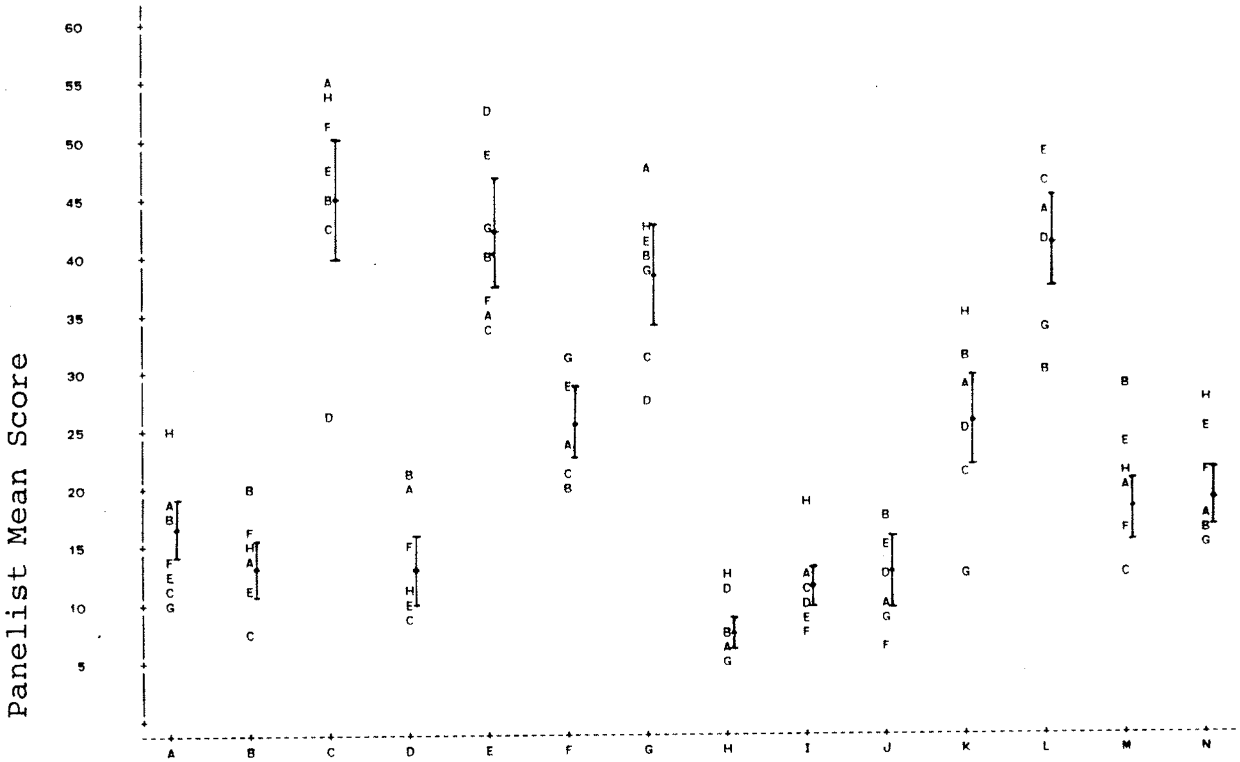
The characteristic, surface contour, was judged for each fabric sample by assessing the amount the fabric surface deviates from a plane according to the procedure drawn up during the development section. Three reference samples were used to demonstrate the increase in surface contour from even/flat (the surface follows a straight line and does not deviate from planeness) to uneven/bumpy (the surface follows a wavy line and does deviate from planeness). The handling technique used to determine the amount of deviation from planeness was by grazing the surface with the whole length of the fingers, applying very little pressure.

The reliability of the individual panelists was examined for the surface contour evaluation and the analysis of variance is presented in Table 17. Each panelist had scores for the fabric samples that were significantly different. Figure 3 illustrates the overall mean scores and their standard deviations together with the mean scores of each panelist, for each fabric sample. The spread of values indicates the variation among the panelists in assessing the magnitude of surface contour.

Table 17. Analysis of Variance for Surface Contour Scores of Individual Panelists.

Panelist	Fabric Samples F-value	Fabric Samples (PR < F)	Replications F-value	Replications (PR < F)
A	14.85	(0.0001)	2.66	(0.1271)
B	5.15	(0.0029)	0.50	(0.4926)
C	15.54	(0.0001)	1.93	(0.1885)
D	24.31	(0.0001)	0.02	(0.8987)
E	15.20	(0.0001)	5.96	(0.0297)*
F	14.13	(0.0001)	2.19	(0.1625)
G	15.03	(0.0001)	0.31	(0.5869)
H	21.94	(0.0001)	1.09	(0.3162)

Note: * F value significantly different at the 0.05 level.



Fabric Samples

Note: 26 observations

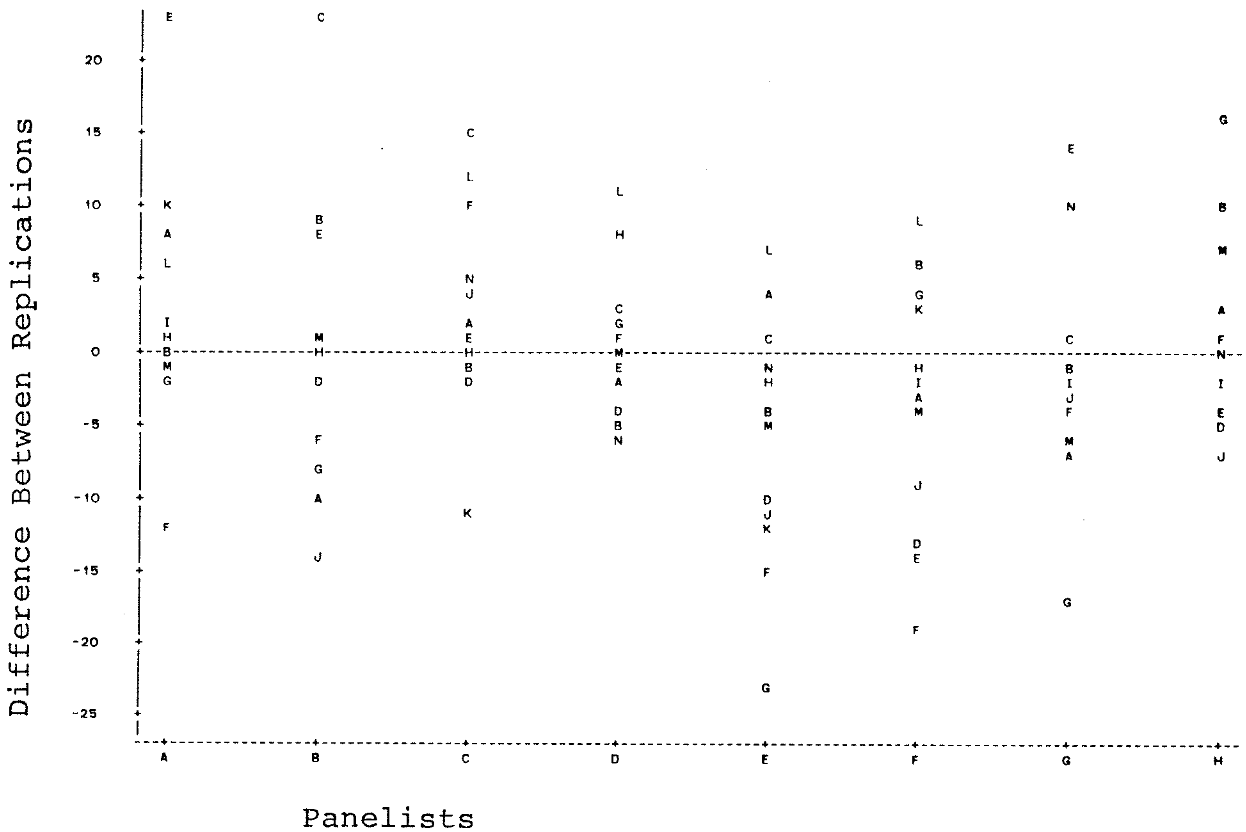
Figure 3. Plot Showing the Mean Surface Contour Scores of Each Panelist for Each Fabric Sample.

Apart from Panelist E, each panelist had scores for the replications that were not significantly different and therefore gave similar assessments. The significant difference for Panelist E indicated that the assessments of surface contour were different for the two replications. (Refer to Table 17.)

The differences between replications one and two of each panelist for each fabric sample are listed in Appendix 6. Figure 4 shows the spread of differences for each panelist. Panelist E is shown to have ten of the fabric sample differences plotted below the zero axis, indicating that higher scores were given in replication two.

As the scores of Panelist E lacked reliability because of the difference between replications, the analysis of variance for the panel given in Table 18 was calculated without Panelist E. A significant F value for fabric samples gives an indication that the fabric samples were distinguished as having different degrees of unevenness of the surface.

The significant F values for panelists indicates that the panelists assessed the fabrics differently. The difference shows up in the ordering of the scores given by the panelists. As can be observed in



Note: 26 observations hidden

Figure 4. Plot Showing the Surface Contour Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

Table 18. Analysis of Variance for Surface Contour Scores of the Panel.

Source	DF	ANOVA SS	F value	PR < F
panelists[1]	6	1914.82	11.68	0.0001*
fabric samples	13	30176.07	84.98	0.0001*
replications	1	1.84	0.07	0.7957
panelists by fabric samples	78	4039.18	1.90	0.0017*
panelists by replications	6	244.23	1.49	0.1904
error	91	2485.68		
total	195	38861.82		

Note: [1] Panelist E was eliminated because of lack of reliability.

* F value was significantly different at the 0.05 level.

Figure 3, Panelists A, B, and H, in most cases, gave higher scores while Panelists C, F, and G, in most cases, gave lower scores. In some instances the scores are over two standard deviations away from the overall mean score.

The factor, replications, was nonsignificant demonstrating the scores for the panel were similar for each replication providing an indication of reliability.

The interaction was nonsignificant for panelists by replications. The interaction for panelists by fabric samples, however, was significant indicating that the panelists differed in their assessment of the surface deviating from a plane, depending on the fabric samples. Figure 3 shows that a wide range of scores were given to certain fabric samples. In some cases, scores for one panelist are found at the high end of the range of scores, while in other cases, scores for that panelist are located at the low end on the range -- demonstrating some interaction.

Observation of the fabric samples that were assessed indicated the presence of surface factors that could affect the perception of the panelists. A few of these will be described. Several samples had rib effects due to yarn or fabric structures used. The structures thus had a 'hills and valleys' effect. This factor may have influenced the results in a manner similar to the perception of grooved metal plates in a study done by Lederman and Taylor (1972). In the study for the perceived roughness of grooved metal plates, they found that variation in the widths of grooves and spacings between the grooves affected the assessments made by the panelists.

In the two structures of knit fabric samples G and K, the hills were close together creating small, narrow valleys that may have gone undetected or been perceived less by some panelists. Fabric samples C and E were structures with uniform ridges on their surface made by low hills and wide valleys which may have been perceived by some panelists but not others. Fabric sample F and L had novelty yarns inserted in the filling direction that contrasted with the flat/even background fabric and gave a hill and valley effect, which would have influenced the surface contour assessment. Scores for fabric sample F appeared to differ in each replication. This may have resulted because of the specimen replacement technique used. The specimens tested could have differed in the number and prominence of slub yarns present, thereby, influencing the assessment.

The results from Tukey's test, to determine which fabrics were significantly different and which were perceived to be similar, from uneven/bumpy to even/flat, were:

C E L G F K N M A B D J I H

Visual observation of the ordering shows common factors within groupings. The first grouping, C, E, L, and G, had fabric samples with ridges formed because of the fabric structure. The hills and valleys created were uniform across the fabric surface. The differences among the fabric samples were the size of the hills and valleys. The second grouping, F and K, was similar to the first grouping except slub yarns were used in construction. The influence of slub yarns in the structure caused them to give an irregular perception of unevenness, this was especially true for fabric sample F. In the third grouping, N, M, A, B, D and J, the surface contour of most of the samples resulted from presence of slub yarns and/or twill weave structures. The ridges were less prominent and varied from fairly uniform to uniform. The exceptions were fabric samples N and J, which were plain weaves with moderate packing factor with spaces (valleys) between the yarns. The fourth and fifth groupings, A, B, D, J, I; and B, D, J, I, H, did not have prominent surface contour characteristics. They were flat twill weave structures, plain weave structures, and a fine gauge jersey knit structure.

Surface Friction

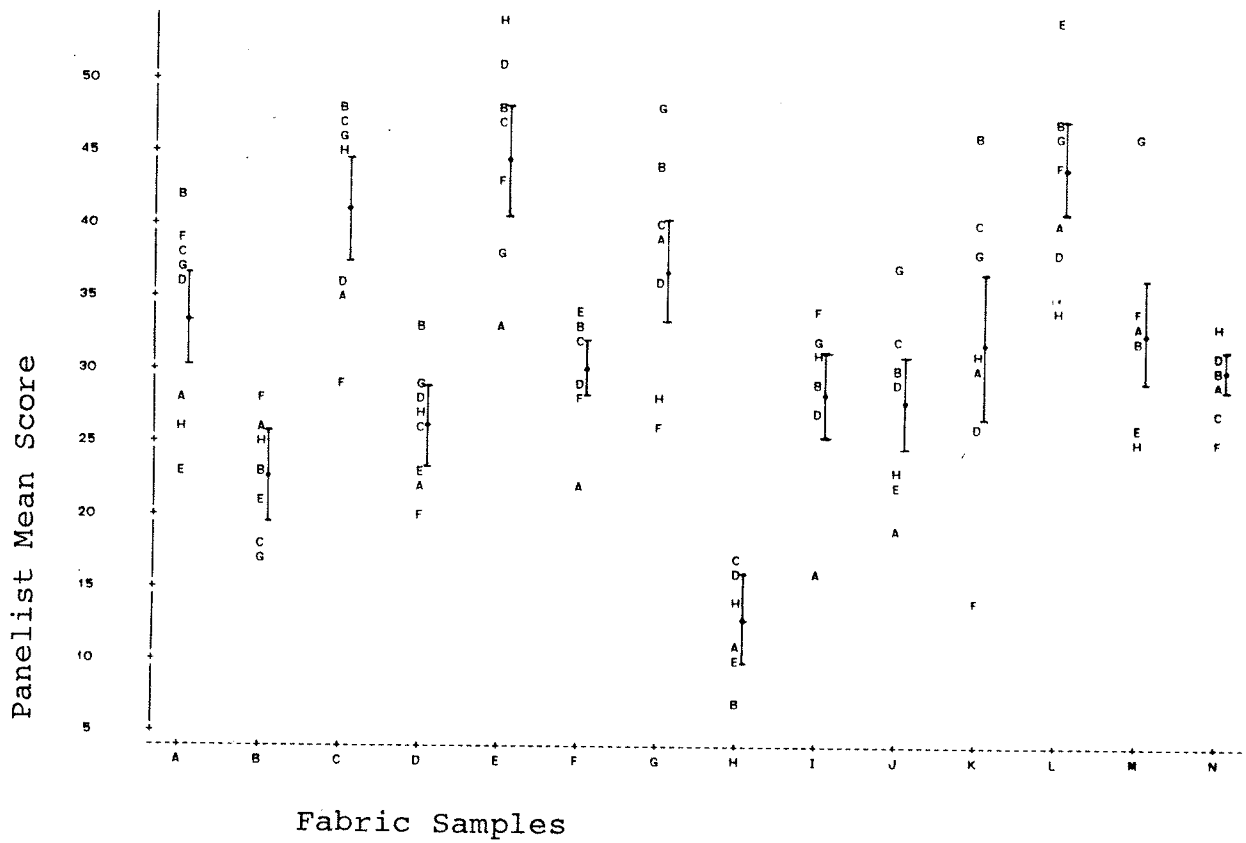
The physical property, surface friction, was evaluated for each fabric sample by assessing the force required to keep the hand moving over the fabric surface and overcoming the resistance to sliding using the developed procedure. Problems were encountered during the development process because the panelists may have had inadequate training or there may have been inherent difficulties in evaluating surface friction. The handling technique finally chosen was one in which the top portion of the fingers grazed the fabric surface with little pressure, in both the warp and filling directions, evaluating the surface friction as the largest amount of resistance offered to the fingers. Three reference samples were used to demonstrate the increase in surface friction from smooth to rough. Smooth was when the hand did not stick to the surface, which offered little to no resistance and a low amount of force was required to keep the hand sliding. Rough was when the hand tended to stick to the surface, which offered resistance and force was required to keep the hand sliding.

The individual panelist reliability for surface friction data was studied and the analysis of variance is presented in Table 19. The panelists had scores for the fabric samples that were all significantly different indicating a difference in the scores for the fabric samples for surface friction. Figure 5 shows the overall mean scores and their standard deviations together with the mean scores of each panelist for each fabric sample. The spread of values indicates the variation among the panelists in assessing the magnitude of resistance to sliding. Scores from the panelists were not significantly different for replications one and two indicating similar assessments were obtained.

The differences between replications one and two of each panelists for each fabric sample are listed in

Table 19. Analysis of Variance for Surface Friction Scores of Individual Panelists.

Panelists	Fabric Samples F value	(PR < F)	Replications F value	(PR < F)
A	5.84	(0.0016)	0.02	(0.8812)
B	9.18	(0.0002)	2.10	(0.1714)
C	6.94	(0.0007)	3.81	(0.0727)
D	5.59	(0.0020)	0.05	(0.8300)
E	11.80	(0.0001)	1.13	(0.3074)
F	4.73	(0.0043)	2.19	(0.1628)
G	16.10	(0.0001)	0.00	(0.9611)
H	11.49	(0.0001)	0.44	(0.5199)



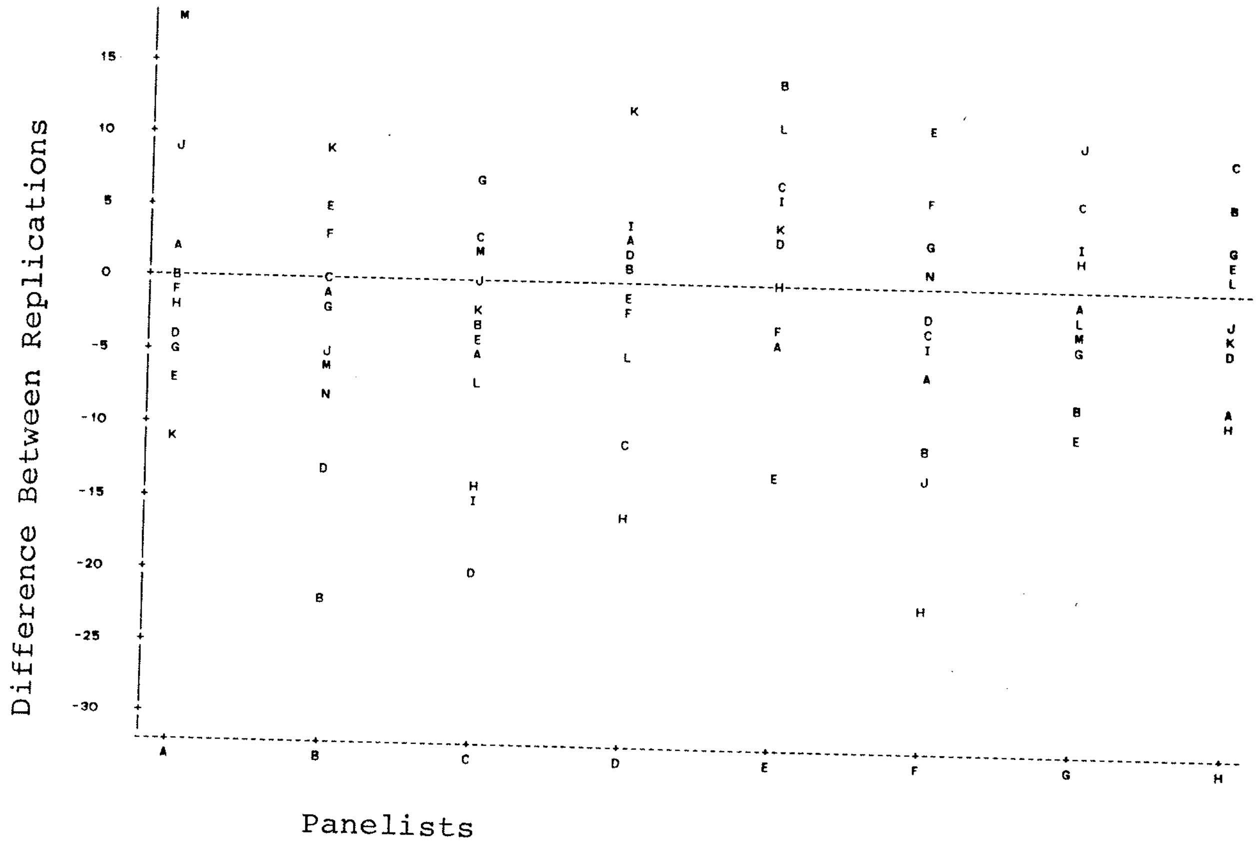
Note: 17 observations hidden

Figure 5. Plot Showing the Mean Surface Friction Scores of Each Panelist for Each Fabric Sample.

Appendix 6. Figure 6 is a plot illustrating these differences and shows the spread of differences for each panelist. The spread of the differences for the panelists were within a similar range.

The panel reliability was studied and the analysis of variance is presented in Table 20. Fabric samples were assessed as having different levels of resistance to sliding across the surface and different amounts of force were required to keep the top portion of the fingers grazing the surface with a little pressure, indicated by the significant F value for fabric samples.

In using the evaluation procedure for surface friction, a significant F value for panelists indicates there may have been a difference in the assessments given to some fabrics. The difference may be a manifestation of the grouping of the scores given by the panelists. By examining Figure 5, one can see that the mean scores of the panelists for some fabric samples are in two groups. For example, scores for fabric samples A, C, F, and J of approximately half the panelists are about one standard deviation above the overall mean score and for the remaining panelists about one standard deviation below.



Note: 28 observations hidden

Figure 6. Plot Showing the Surface Friction Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

Table 20. Analysis of Variance for Surface Friction Scores of the Panel.

Sources	DF	ANOVA SS	F value	PR < F
panelists	7	1475.99	8.71	0.0001*
fabric samples	13	15224.38	48.39	0.0001*
replications	1	54.51	2.25	0.1365
panelists by fabric samples	91	5639.18	2.56	0.0001*
panelists by replications	7	226.02	1.33	0.2411
error	104	2517.10		
total	223	25137.18		

Note: * F value was significantly different at the 0.05 level.

Between replications one and two, there was nonsignificant difference indicating that the scores for the panelists were similar for the replications and giving an indication of reliability.

The interaction was not significantly different for panelists by replications but there was a significant interaction for panelists by fabric samples. (Refer to Table 20.) The interaction for panelists by fabric samples showed that the panelists assessed the amount of force needed to keep the top portion of the fingers sliding differently depending on the fabric sample. In some cases, scores for one panelist are found at the high end of the range of scores, while in other cases scores for the same panelist are located at the low end of the range. (Refer to Figure 5.)

Observation of the fabrics that were evaluated indicated no clear trend as to which surface factors might evoke different perceptions. While both yarn and fabric structures affected how the panelists perceived surface friction, the fabric structure appeared to have more influence on the surface friction if the structure itself was uneven. When the fabric structure resulted in a flat surface, then the yarn structure had the greater influence.

Steven and Harris (1962) examined roughness using samples of emery cloth and found that the manner in which the particles protruded from the surface influenced the roughness judged. Fabric samples A, C, and M, which were constructed with spun yarns of low to medium twist in low to moderately compact twill weave, may have influenced the panelists in the amount of roughness percieved from individual protruding fibres or filament loops. Fabric samples F and D which were composed of spun yarns with medium twist in a compact fabric structure had a similar effect to a smaller degree.

Lederman (1974) and Lederman and Taylor (1972) indicated that the results of their studies on the perceived roughness of grooved plates may have been influenced by the widths of the grooves and by the areas between the grooves. In the present study, the perceived roughness of fabric surface may have been influenced, in a similar manner, by the varying widths and areas between the hills and valleys of grooves.

Another factor that appeared to influence the roughness was the stretchiness. Fabric samples C, E and K, because of their knit structure, stretched as the panelists slid their fingers over the surface. The amount of stretch may have influenced the force used to overcome the resistance to sliding.

Further analysis using Tukey's test was done to determine which fabrics were significantly different and which were perceived to be similar. The results from, rough to smooth, were:

E L C G A M K F N I J D B H

Visual observation of the fabrics indicated common factors within groupings. The first grouping, E, L and C, had ridges protruding from the surface as a result of the fabric structure. The second grouping consisting of C and G had round ridges due to the fabric structure with those of G being smaller and further apart. The third grouping composed of G, A and M had a flatter surface resulting from rib knit and twill weave structures. They were made from spun yarns with low twist. The last three groupings, A, M, K, F, N, I, J; K, F, N, I, J, D; and I, J, D, B; had similar structural details that varied to a small degree. The fabrics in the groupings were constructed with spun yarns with low to medium amount of twist and were twill and plain weaves. The surfaces of the twill weaves were not as smooth as the surfaces of the plain weaves. The fabrics in the groupings of K, F, N, I, J, D; and I, J, D, B; were produced using spun yarns with medium amount of twist. The structures were plain and twill weaves and showed an increase in compactness resulting in a flatter surface.

Compressibility

The physical property, compressibility, was judged for each fabric sample by assessing the ability for the fabric to be reduced in thickness when compressed or squeezed according to the procedure drawn up during the development of standards and procedures. Three reference samples were used to demonstrate the increase in compression from noncompressible to compressible. Noncompressible was when the fabric sample did not reduce in thickness when pressure was applied, there was no give to the fabric when pressed; hard. Compressible was when the fabric sample decreased in thickness when pressure was applied, the fabric sample gave easily when pressed; soft. The handling technique used to determine the compressibility was by pressing down slowly, using the full length of the fingers, with a pressure equaling the pressure needed to displace a top loading balance by approximately 50 g.

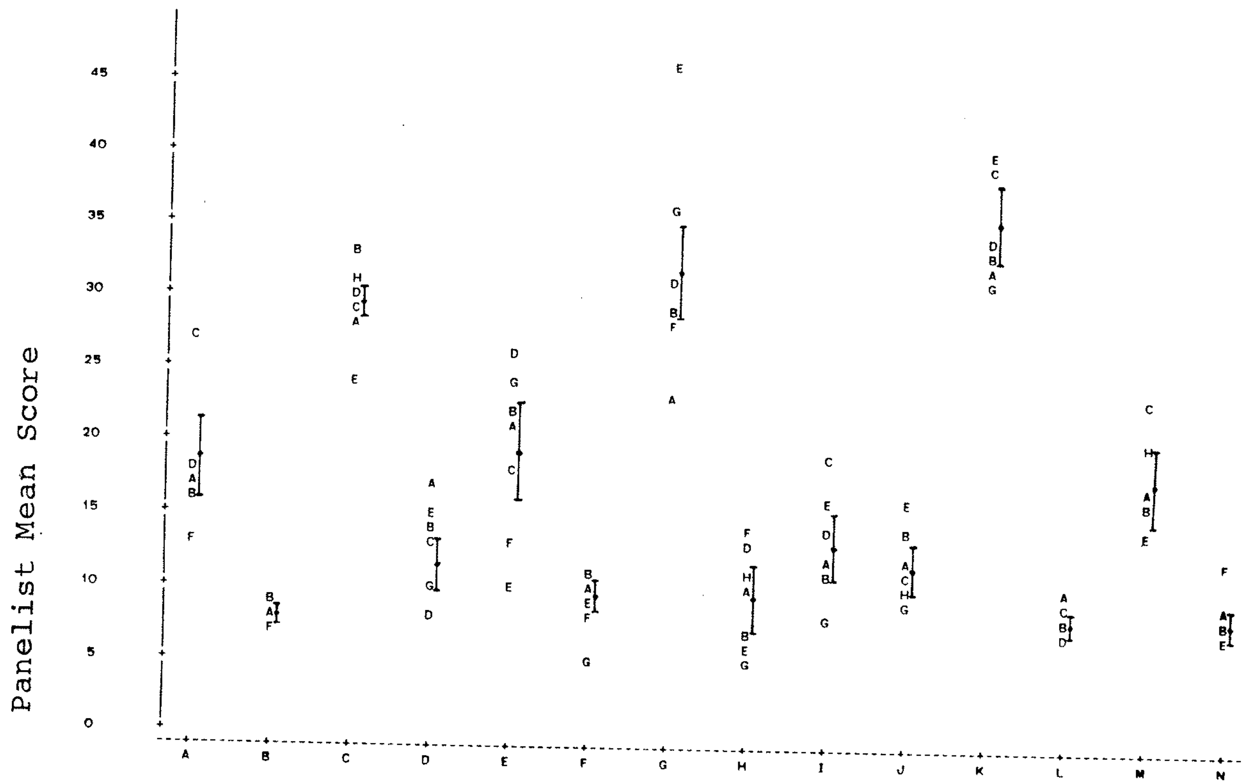
The reliability of the individual panelists was studied and the analysis of variance is presented in Table 21. Scores of the panelists for the fabric samples were significantly different demonstrating a percieved difference among the fabric samples. Figure 7 shows the overall mean scores, the standard deviation and the mean scores of each panelists for each fabric sample. The range of values indicates the variation among panelists in judging the compression.

Except for Panelists E and H, the panelists had scores for replications that were not significantly different and therefore obtained similar assessments. Replication scores for Panelists E and H were significantly different indicating they did not give similar assessments of compressibility for some samples. (Refer to Table 21.) The differences between replications one and two of each panelist for each fabric sample are listed in Appendix 6. Figure 8 shows the differences for each fabric and indicates the spead of difference values for each panelist. Scores of Panelist E and H were higher in replication

Table 21. Analysis of Variance for Compressibility Scores of Individual Panelists.

Panelists	Fabric Samples F value	Fabric Samples (PR < F)	Replications F value	Replications (PR < F)
A	23.99	(0.0001)	2.66	(0.1271)
B	12.24	(0.0001)	1.86	(0.1958)
C	14.99	(0.0001)	4.06	(0.0649)
D	25.03	(0.0001)	0.00	(0.9728)
E	14.17	(0.0001)	8.22	(0.0132)*
F	4.43	(0.0058)	1.02	(0.3304)
G	20.46	(0.0001)	1.12	(0.3091)
H	14.42	(0.0001)	5.22	(0.0398)*

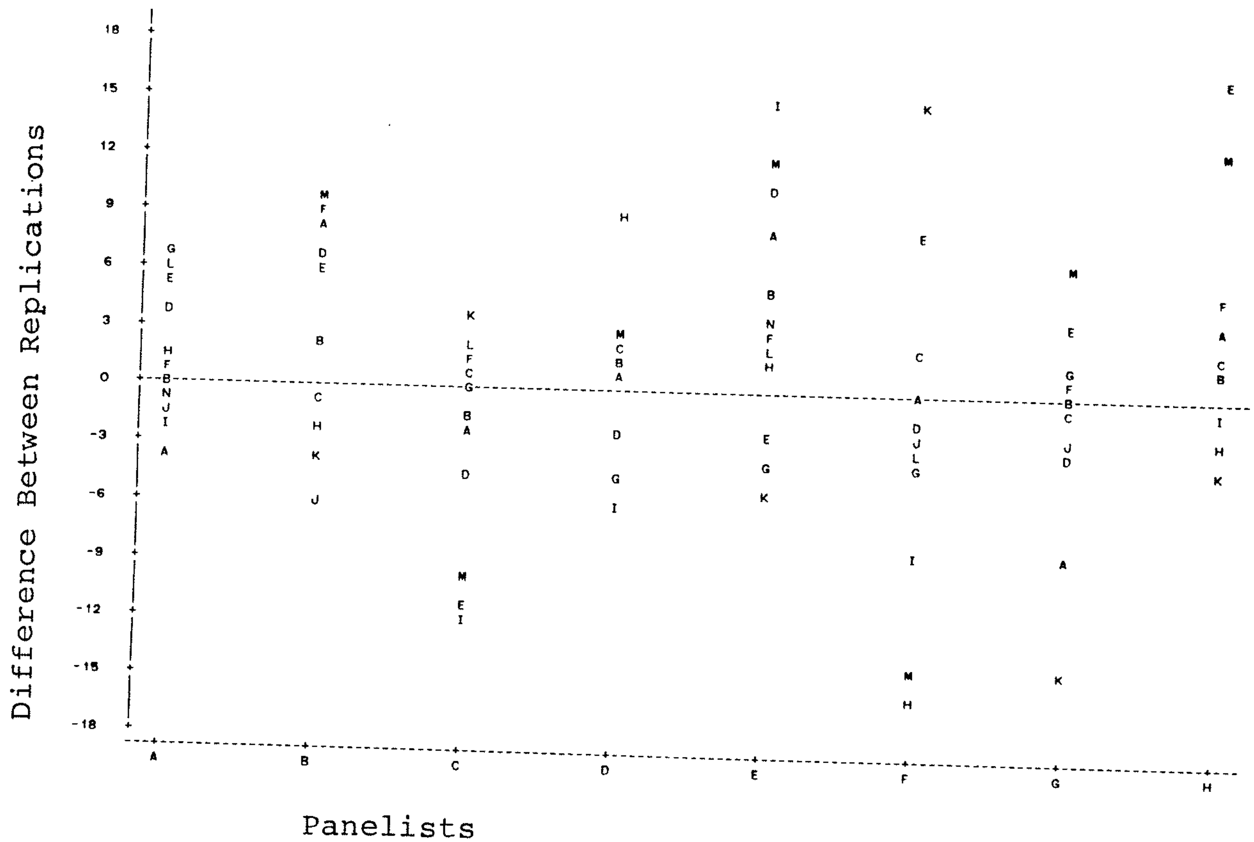
Note: * F value was significantly different at the 0.05 level.



Fabric Samples

Note: 36 observations hidden

Figure 7. Plot Showing the Mean Compressibility Scores of Each Panelist for Each Fabric Sample.



Note: 30 observations hidden

Figure 8. Plot Showing the Compressibility Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

one than in two, with most of the differences located above the zero axis.

Since scores of Panelists E and H lacked reliability because of the large variation in reproducing the assessments, they were excluded from the analysis. The analysis of variance given in Table 22 was calculated eliminating Panelists E and H. From the analysis, the significant F value for fabric samples gives an indication that the fabric samples were judged to have different degrees of compression.

The factors, panelists and replications, had nonsignificant F values showing similar panelist assessment and similar assessment over replications one and two.

The nonsignificant interaction between panelists and fabric samples indicated that the panelists were evaluating the fabrics in a similar manner in each replication. The nonsignificant interaction for the panelists by replications factor indicated similar scores were assessed in the replications. (Refer to Table 22.)

Further analysis was done using Tukey's test to determine which fabrics were significantly different and which were perceived similar. The results, from

Table 22. Analysis of Variance for Compressibility Scores of the Panel.

Sources	DF	ANOVA SS	F value	PR < F
panelists[1]	5	129.35	1.86	0.1104
fabric samples	13	12396.13	68.50	0.0001*
replications	1	10.25	0.74	0.3934
panelists by fabric samples	65	1312.97	1.45	0.0578
panelists by replications	5	127.06	1.83	0.1166
error	78	1085.81		
total	167	15061.57		

Note: [1] Panelists E and H were eliminated because of lack of reliability.

* F value was significantly different at the 0.05 level.

compressible to noncompressible, were:

K C G E A M I D J H F N L B

The first, second and third groupings, K, C; C, G; and E, A, M; were the knit structures and woolen wovens which allowed easy compression. The overlapping that resulted for C may have been from the variability in the scores. The fourth and fifth groupings, I, D, J, H, F, N, L; and D, J, H, F, N, L, B; were rated quite close together because the difference in compression may not have been readily perceived by the panelists. They were thinner fabrics and when compressed instrumentally, the change in compression between fabric samples was approximately 0.10 mm.

From visual observation and knowledge of the fibre content, there were various interrelating factors that appeared to influence the compression of the fabric samples. These were the fibre content, yarn density, fabric density and fabric thickness. For the knit structures, observation of knit fabrics, E, G, H, and K, indicated that compression may have been influenced by the tightness of the loop structure and the thickness. (Refer to Figure 7.) Elder, et al. (1984A), when examining the softness and compression of woven wools using a similar technique, also found that fabric thickness and density influenced the compression.

Elder, et al. (1984A) made similar observations about the ability to discern compression differences. They believed that the limit of compressional deformation that a person can discern lies between 0.05 and 0.10 mm. In the present study, approximately 0.10 mm was found as a limit. Similarly, Elder, et al. indicated that a person would not be able to distinguish compression differences between fabrics when the differences were within 0.05 and 0.10 mm of each other. In the present study, the panelists could discern compression differences between the fabric samples of aproximately 0.10 mm. However the difference between fabric samples K and C, where the difference was 0.48 mm, was not detected.

Flexibility

The physical property, flexibility, was evaluated for each fabric sample by assessing the amount of ease with which the fabric deforms or the resistance offered by the fabric to deformation according to the developed procedure. Problems were encountered during the development of the procedure for flexibility, especially in the selection of a handling technique. Two techniques were contemplated. The first was to place the fabric sample flat on the palm of the hand and to raise the fingers thereby forcing the fabric to form a "U" shape. The resistance offered would then be used as an assessment of the stiffness. Limp fabrics were not easily assessed by this technique because they tended to fall away from the fingers during the evaluation. The second technique considered was to place the fabric sample on the table, gently fold the specimen back on itself and then by pressing down on the fold to evaluate the stiffness by the amount of resistance to pressure that is felt by the fingers. This last technique was chosen because it could be used for the wide range of fabrics used in the study. Three reference standards were employed to demonstrate the increase in flexibility from limp (the fabric sample did not resist the deformation) to stiff (the fabric sample resisted the deformation).

The individual panelist reliability was examined

Table 23. Analysis of Variance for Flexibility Scores of Individual Panelists.

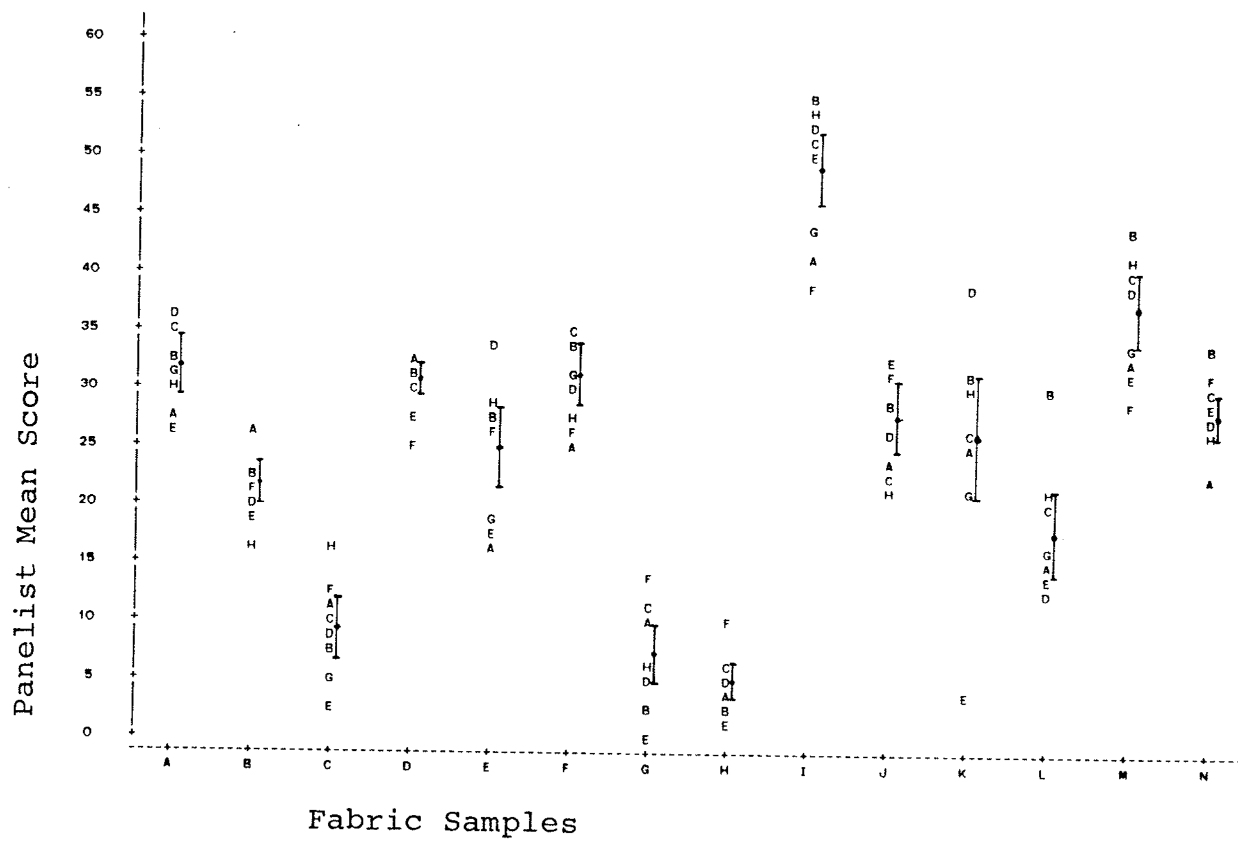
Panelists	Fabric Samples F value	Fabric Samples (PR < F)	Replications F value	Replications (PR < F)
A	9.09	(0.0002)	3.96	(0.0680)
B	24.91	(0.0001)	4.95	(0.0444)*
C	14.03	(0.0001)	0.20	(0.6587)
D	32.21	(0.0001)	0.67	(0.4272)
E	27.53	(0.0001)	1.50	(0.2423)
F	2.35	(0.0681)[NS]	4.65	(0.0505)
G	16.03	(0.0001)	3.22	(0.0958)
H	22.35	(0.0001)	12.89	(0.0033)*

Note: [NS] F value was not significantly different at the 0.05 level.

* F value was significantly different at the 0.05 level.

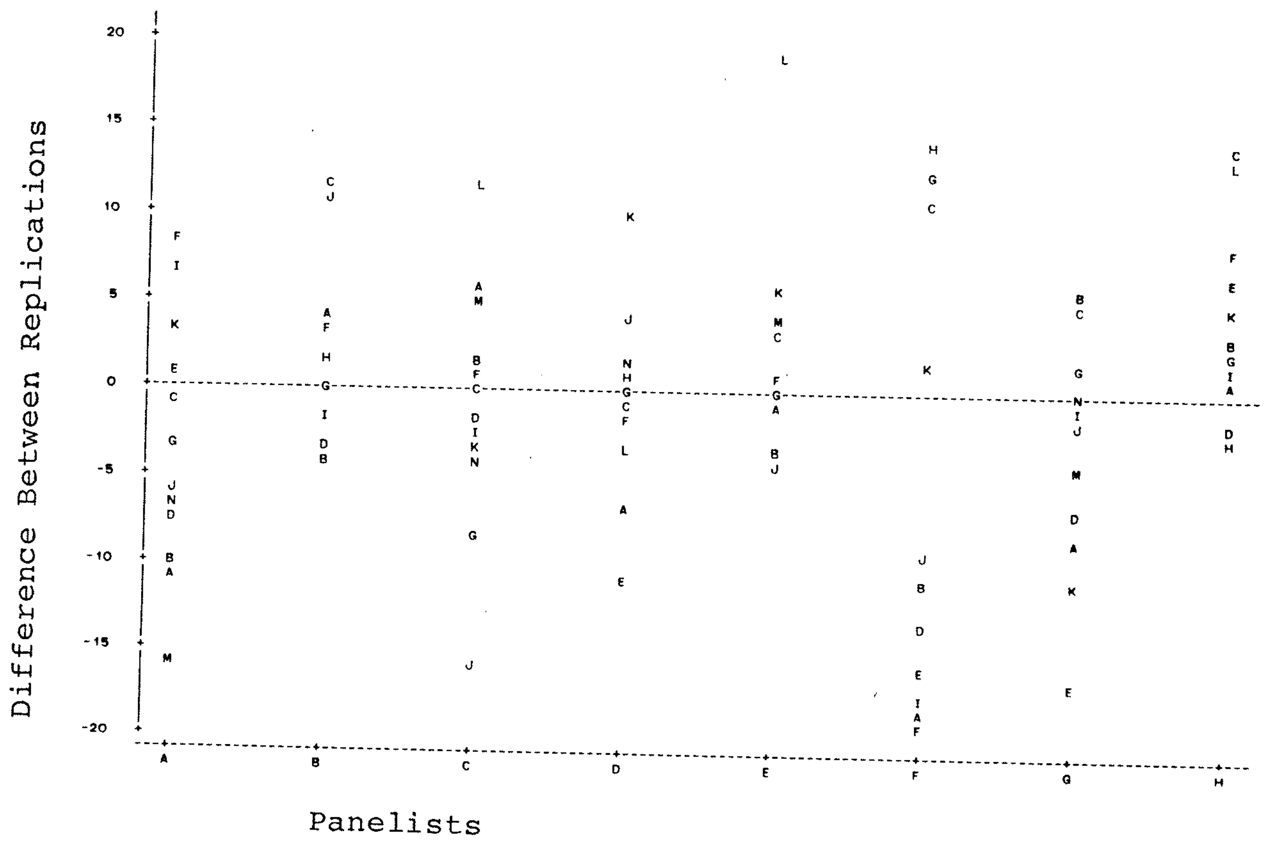
and the analysis of variance is presented in Table 23. Apart from Panelist F, the panelists had scores for the fabric samples that were significantly different. Scores for Panelist F were not significantly different for the factor, fabric samples, indicating a similarity among the scores for the fabric samples. Figure 9 shows the nature of the variation in the panelist mean scores relative to the overall mean scores for each fabric. The mean scores for Panelist F were, in many cases, different from the overall mean scores for stiffness. For example, scores for fabric samples C, F, J, and N, given by Panelist F varied by at least plus or minus one standard deviation from the overall mean score and scores for fabric samples D, G, H, I, and M varied by at least plus or minus two standard deviations.

The scores for the panelists, except for Panelists B and H, were not significantly different for the factor, replications. This indicated similar assessments were given for the replications. Panelists B and H had significantly different scores for replications indicating a difference in their assessments of flexibility. (Refer to Table 23.) The differences between replications one and two of each



Note: 15 observations hidden

Figure 9. Plot Showing the Mean Flexibility Scores of Each Panelist for Each Fabric Sample.



Note: 27 observations hidden

Figure 10. Plot Showing the Flexibility Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

panelist for each fabric sample are listed in Appendix 6. Figure 10 shows these differences and the spread of differencs for each panelist. Scores for Panelists B and H were higher in replication one than in two, with most of the differences located above the zero axis.

As the scores of Panelist B, F, and H lacked reliability, the analysis of variance given in Table 24 for the flexibility results was calculated without Panelists B, F, and H. The significant F value for fabric samples gives an indication that the fabric samples were distinguished as having different levels of stiffness.

In using the evaluation procedure for flexibility, the significant F value for panelists indicates there may have been differences in the assessments given to the fabric samples. In Figure 9, the difference shows up in the ordering of the scores given by the panelists, for example scores given by Panelist A were usually at the low end of the range of the scores and Panelist G were usually at the high end of the range, and in the grouping of the scores given by panelists, for example, as noted for fabric samples E, I, and M.

Between replications one and two, there was a

Table 24. Analysis of Variance for Flexibility Scores of the Panel.

Source	DF	ANOVA SS	F value	PR < F
panelists[1]	4	786.58	10.63	0.0001*
fabric samples	13	19480.49	80.97	0.0001*
replications	1	61.78	3.34	0.0723
panelists by fabric samples	52	2269.67	2.36	0.0006*
panelists by replications	4	129.35	1.75	0.1503
error	65	1202.88		
total	139	23930.74		

Note: [1] Panelists B, F, and H were eliminated because of lack of reliability.

* F value was significantly different at the 0.05 level.

nonsignificant difference demonstrating the scores for the panelists were similar, providing an indication of reliability.

The interaction was not significant for panelists by replications. The significant interaction for panelists by fabric samples indicated the panelists differed in the way they assessed the stiffness, depending on the fabric sample. (Refer to Table 24.) In some cases, scores for one panelist are found at the end of the range of scores, while in other cases, scores are located for the same panelist at the low end of the range -- demonstrating some interaction. (Refer to Figure 9.)

From observation of the fabric samples that were evaluated, several physical factors appeared to influence the perception of the panelists. These were the mobility of the yarns within the structures, fabric thickness and ability of the fabric to compress when bent. The fabric samples were C, E, G, and K (knit structures), I (a woven wool blend bonded to a tricot knit), and M (a woven woolen). Elder, et al. (1984B), in a study of woven woolen fabrics similarly found that weight and thickness affected the perception of the flexibility by the panelists.

Further analysis was done using Tukey's test to determine which fabric samples were perceived different and which were perceived similar. The results, from stiff to limp, were:

I M A D F N K J E B L C G H

The first grouping, M and A were twill weave woolen structures ranging from compact to moderately compact with a moderately high thickness compared to the other fabric samples. The second grouping, A, D, F, N, K, J and E, were fabrics made from several fibre contents and fabric structures. Fabric sample D was a herringbone which was thinner than A. Fabric samples F and N were plain weave structures and were thinner than the other fabrics in the group. Fabric samples K, J and E had a degree of looseness in their structures which made them appear limper to the panelists than the thinner fabric samples D, F and N. Similar thickness and looseness of weave structure were characteristics of the third and fourth groupings, J, E, B; and B, L. The last grouping, C, G and H, were knit structures that varied in thickness but the yarns had mobility within the structures and bent easily during the sensory evaluation.

Thickness

The physical property, thickness, was evaluated for each fabric sample by assessing the distance between the upper and lower surfaces of the fabric sample that the finger and thumb assessed using the developed procedure. Three references were used to indicate the increase in thickness along the scale from thin (the distance between the finger and thumb was small) to thick (the distance between the finger and thumb is great). The handling technique used to evaluate thickness was by assessing the distance between the thumb and finger by gently moving the thumb over the edge.

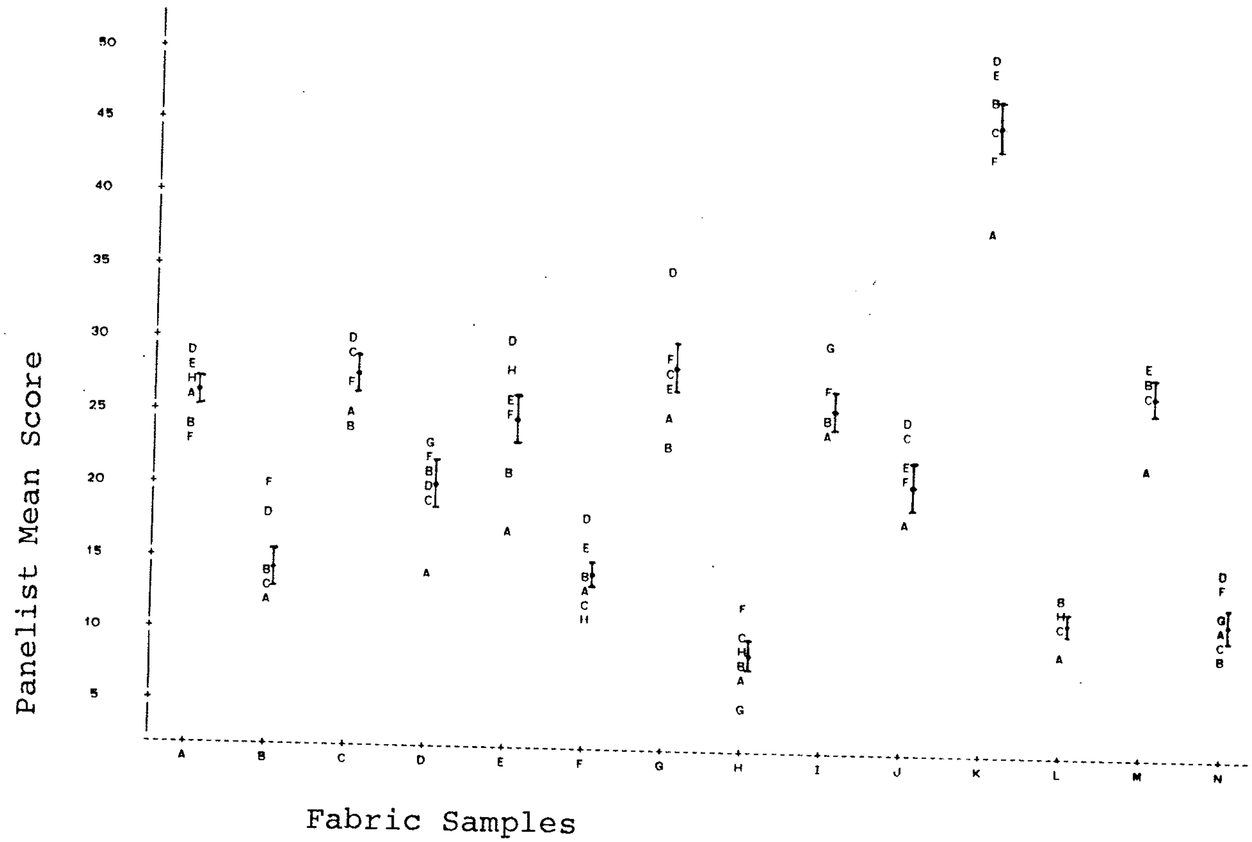
The individual panelist reliability was studied and the analysis of variance is presented in Table 25. The panelists had scores for fabric samples that were significantly different. Figure 11 is a plot which shows the panelists scores along with the overall mean scores and standard deviations. The spread of values indicates the variation among the panelists in assessing the thickness.

Panelist scores for replications were not

Table 25. Analysis of Variance for Thickness Scores of Individual Panelists.

Panelists	Fabric Samples F value	(PR < R)	Replications F value	(PR < R)
A	53.17	(0.0001)	0.05	(0.8235)
B	23.45	(0.0001)	1.03	(0.3281)
C	50.94	(0.0001)	3.06	(0.1039)
D	60.78	(0.0001)	14.66	(0.0021)*
E	23.74	(0.0001)	1.36	(0.2641)
F	61.18	(0.0001)	2.28	(0.1552)
G	18.34	(0.0001)	5.04	(0.0428)*
H	29.17	(0.0001)	0.16	(0.6949)

Note: * F value was significantly different at the 0.05 level.



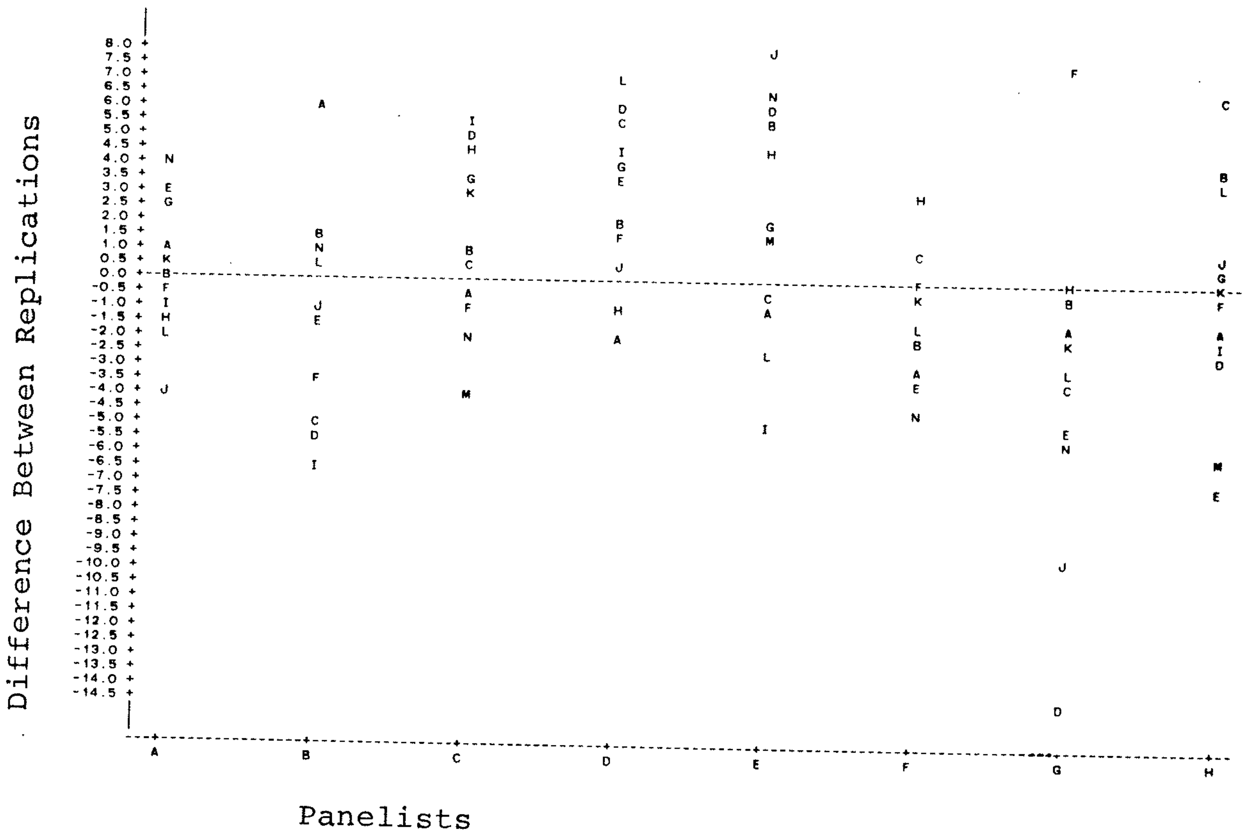
Note: 37 observations hidden

Figure 11. Plot Showing the Mean Thickness Scores of Each Panelist for Each Fabric Sample.

significantly different except for Panelists D and G, indicating the Panelist D and G were not giving similar assessments of thickness for the two replications. The differences between replications one and two of each panelist for each fabric sample are listed in Appendix 6. Figure 12 shows these differences and the spread of differences for each panelist. The differences in scores between replications one and two were located almost entirely above the zero axis for Panelist D and almost entirely below for Panelist G, demonstrating a change in assessment between replications.

As the scores for Panelists D and G lacked reliability because of the significant difference for the replications, the analysis of variance given in Table 26 for the thickness results was calculated eliminating Panelists D and G. A significant F value for fabric samples was an indication that the fabric samples were distinguished as having different thicknesses.

The factor, panelists, also had a significant F value, indicating the panelists, included in the analysis, may have been evaluating the samples differently. The difference may be reflected in the



Note: 26 observations hidden

Figure 12. Plot Showing the Thickness Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

Table 26. Analysis of Variance for Thickness Scores of the Panel.

Source	DF	ANOVA SS	F value	PR < F
panelists [1]	5	321.92	11.98	0.0001*
fabric samples	13	13509.48	190.10	0.0001*
replications	1	0.01	0.00	0.9606
panelists by fabric samples	65	546.73	1.54	0.0344*
panelists by replications	5	38.73	1.42	0.2266
error	78	426.38		
total	167	14843.25		

Note: [1] Panelists D and G were eliminated because of lack of reliability.

* F value was significantly different at the 0.05 level.

ordering of the panelists along the range of scores for the fabric samples, for example, Panelist E was usually at the high end of the range and Panelist A was usually at the low end. (Refer to Figure 11.)

There was a nonsignificant difference for replications, demonstrating similar scores for the two replications and providing an indication of panel reliability.

The interaction for panelists by replications was not significant but the interaction for panelists by fabric samples was significant. (Refer to Table 26.) The significant interaction for panelists by fabric samples indicated the panelists differed in the way they assessed the thickness, depending on the fabric sample. In some cases, scores for a panelists can be located either at the high or low ends of the range for scores. Observation of the fabric samples that were evaluated suggests that fabric structure influenced the perception of thickness. Scores for fabric samples E, G, and K were more diverse than those found for the other fabrics. The reason may be that these were knit structures that compressed easily making sensory evaluation of thickness difficult.

Further analysis was done using Tukey's test to determine which fabric samples were significantly different and which were similar. The results, from thick to thin, were:

K G C M A I E J D B F L N H

The groupings of the fabric samples indicated which ones the panelists perceived as similar. The first grouping, G, C, M, A and I, had a total difference in thickness of approximately 0.70 cm. Because these fabrics were made of yarns and constructions that resulted in a low density, they compressed easily under the pressure added by the thumb. There were larger differences between the fabric samples G, C and D, M than between M, A and A, I. The other similar groupings had a total difference in thickness of approximately 0.02 - 0.03 cm. These fabrics had structures that resulted in a medium density, they compressed less easily under the pressure added by the thumb.

Weight

The physical property, weight, was judged for each fabric sample by assessing the heaviness of the fabric samples using the developed procedure. Three references were employed to demonstrate the increase in weight along the scale from light (the fabric sample had a small weight) to heavy (the fabric sample had a large weight). The handling technique used to evaluate weight was by holding the entire specimen in the palm of the hand and lifting gently.

The individual panelist reliability was examined and the analysis of variance is presented in Table 27. Apart from Panelist F, the other panelists had scores for the fabric samples that were significantly different. Scores for panelist F were not significantly different for the factor, fabric samples, indicating similarity in the scores. Figure 13 shows the nature of the variation in the panelists mean scores relative to the overall mean scores for weight. The mean scores for Panelist F were, in many cases, different from the overall mean scores. For example, the scores for fabric samples D, F, H, and N, given by Panelist F varied by at least plus or minus one standard deviation and the scores for fabric samples B, E, G, I, and M, varied by at least plus or minus two standard deviations from the mean.

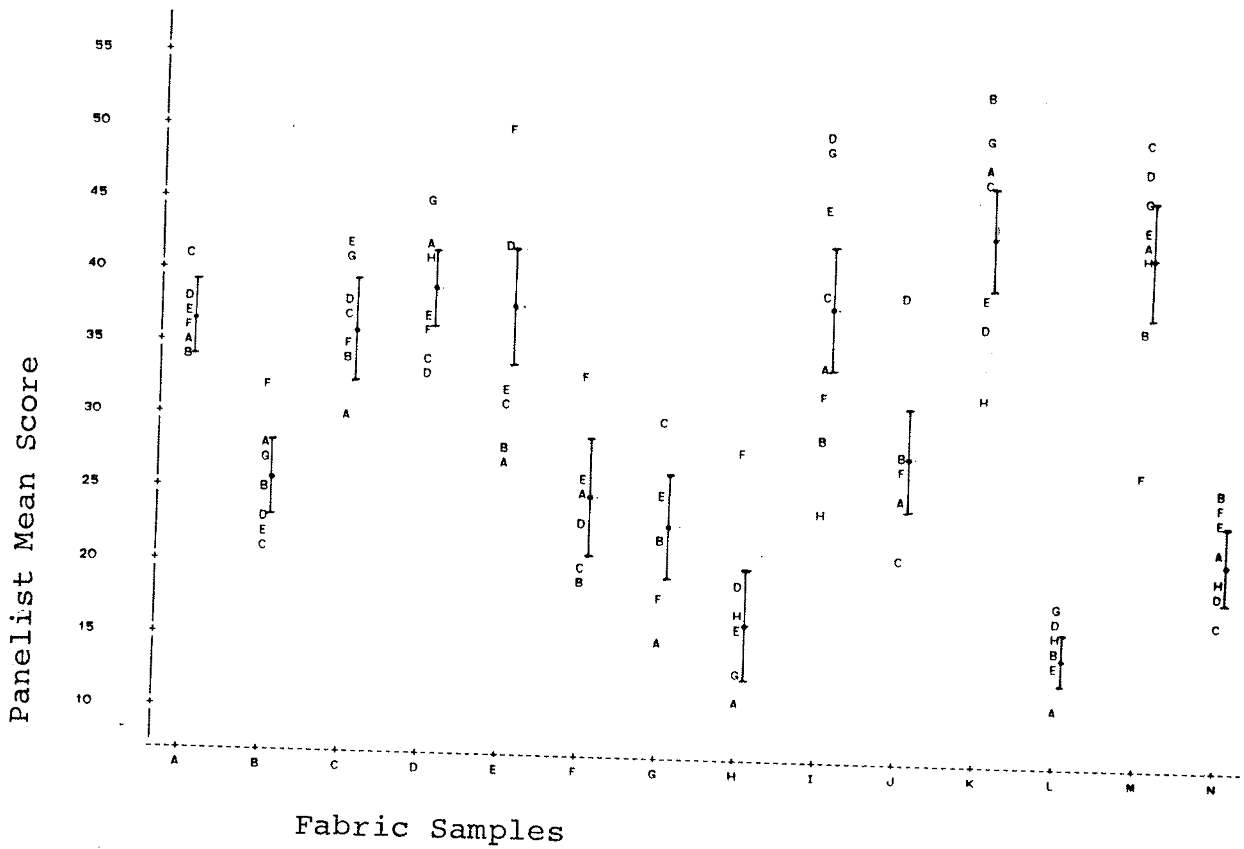
Apart from Panelist C, the panelists scores for

Table 27. Analysis of Variance for Weight Scores of Individual Panelists.

Panelists	Fabric Samples F value	Fabric Samples (PR < F)	Replications F value	Replications (PR < F)
A	4.95	(0.0035)	2.47	(0.1402)
B	5.93	(0.0015)	0.14	(0.7158)
C	33.53	(0.0001)	9.49	(0.0088)*
D	6.87	(0.0007)	0.86	(0.3712)
E	8.22	(0.0003)	0.00	(0.9559)
F	1.65	(0.1901)[NS]	0.75	(0.4035)
G	8.40	(0.0002)	2.85	(0.1151)
H	4.20	(0.0073)	0.64	(0.4364)

Note: [NS] F value was not significantly different at the 0.05 level.

* F value was significantly different at the 0.05 level.

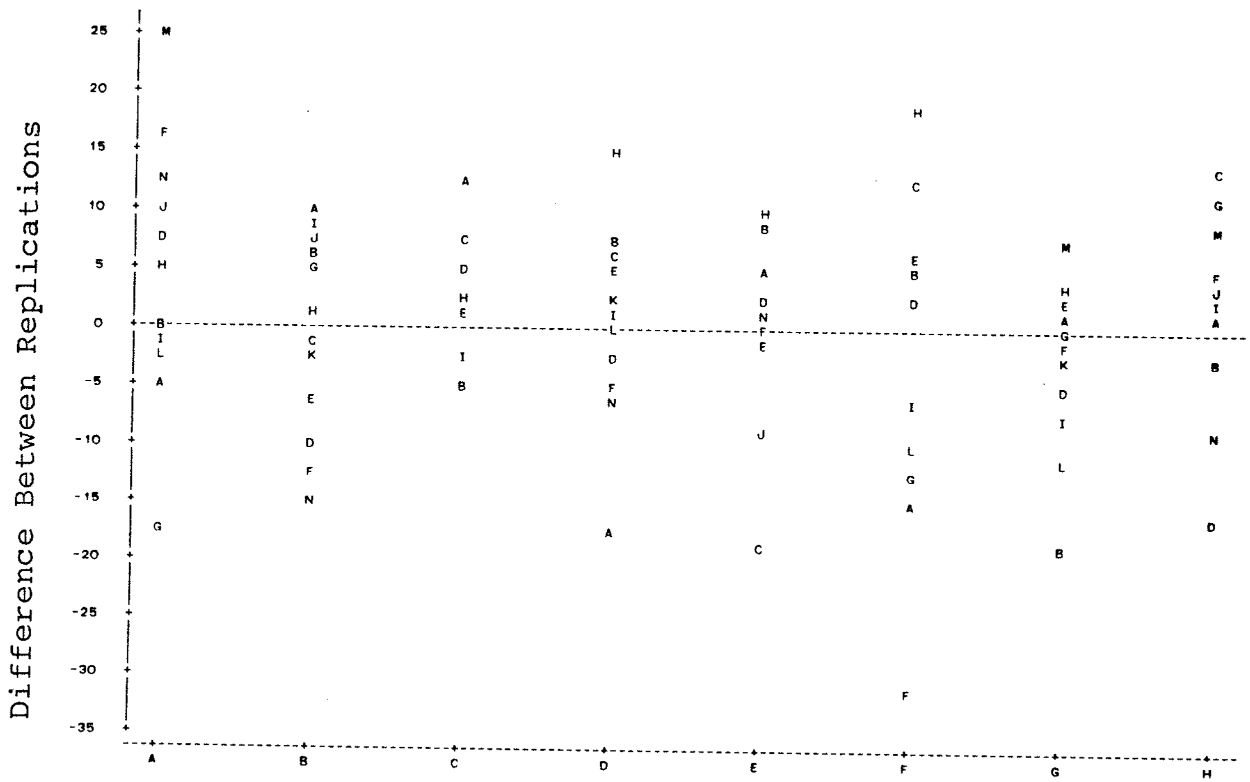


Note: 21 observations hidden

Figure 13. Plot Showing the Mean Weight Scores of Each Panelist for Each Fabric Sample.

the replications were not significantly different and therefore the panelists were assumed to have given similar assessments for the two replications. The significant difference for replications shown for Panelist C indicates this panelist was not providing similar assessments of weight. (Refer to Table 27.) The differences between replications one and two for each panelist for each fabric sample are listed in Appendix 6. Figure 14 is a plot of these differences and shows the spread of differences for each panelist. Panelist C is shown to have most of the fabric sample differences located above the zero axis, indicating higher scores were given in replication one than in replication two.

As the scores for Panelists C and F lacked reliability, the analysis of variance given in Table 28 for the weight results was calculated eliminating Panelists C and F. A significant F value for fabric samples gives an indication that the fabric samples were distinguish as having different weights. In using the evaluation procedure for weight, the significant F value for panelists indicates there may have been diversity in the way the individual panelists assessed the samples. Some of this



Panelists

Note: 31 observations hidden

Figure 14. Plot Showing the Weight Score Differences for Fabric Samples Between Replications One and Two for Each Panelist.

Table 28. Analysis of Variance for Weight Scores of the Panel.

Source	DF	ANOVA SS	F value	PR < F
panelists[1]	5	715.21	3.93	0.0032*
fabric samples	13	14603.18	30.97	0.0001*
replications	1	14.29	0.39	0.5321
panelists by fabric samples	65	3057.21	1.30	0.1357
panelists by replications	5	262.89	1.45	0.2152
error	78	2829.57		
total	167	21480.35		

Note: [1] Panelists C and F were eliminated because lack of reliability.

* F value was significantly different at the 0.05 level.

difference shows up in the ordering of the scores given by the panelists, for example scores of Panelist D were usually at the high end of the range of scores and those of Panelist A were usually at the low end of the range. For some fabric samples, such as E and K, all the scores were plus or minus more than one standard deviation away from the mean.

A nonsignificant F value for replications indicate similar assessments were made between replications one and two suggesting reliability.

The interactions were nonsignificant for panelists by replications and for panelists by fabric samples. (Refer to Table 28.) Observation of the fabric samples that were evaluated indicated no specific reason why the panelists might have had difficulty in evaluating the fabric samples for weight. However, the panelist scores for the weight of fabric samples C, G, I, and K showed wide variation. Sample I was a woven wool fabric that was bonded to a tricot knit while the others were knit structures. The reason for this variation may have been that these fabrics were bulkier and were perceived as being heavier than they were relative to the less bulky fabrics.

Further analysis was done using Tukey's test to determine which fabric samples were perceived different and which were perceived to be similar. The results, from heavy to light, were:

K M D I A C E J B F G N H L

The range of weight within the groupings varied. Fabric sample groupings located at the higher and lower intensity levels of the scale had a wider total difference between the heaviest and lightest weight fabric samples, the range being 100 - 150 g/m^2 whereas fabric sample groupings located at the middle intensity of the scale had a range of 20 - 40 g/m^2. There appeared to be a limit to the weight difference the panelists could discern between the fabric samples. This limit lay between 20 - 30 g/m^2.

Summary

In summary, the analysis of the sensory evaluation results for panel reliability showed that for all physical properties the factor, fabric samples, was significantly different. This indicated that the panel's scores showed a difference among the fabric samples. This was expected since the fabric samples had been selected to cover a range of property intensities. The factor, replications, was always nonsigificant indicating that the panel's scores for the replications were similar. These two results suggest panel reliability.

The factor, panelists, was not always nonsignificant indicating differences in perception of properties by different panelists. The reasons for this result were varied. One reason may have been the placement of the panelists scores on the scale. In some instances, the placement may reflect panelist perception of the line scale and a tendency to give consistently higher or lower scores than the other panelists.

Another reason for the significant F values may have been the amount of training the panel received. It may not have been sufficient for those properties that were significantly different for the factor, panelists. Insufficient training might have caused panelists to use different criteria for evaluating the fabric samples. For example, flexibility was significantly different for panelists, even after three panelists were eliminated for lack of reliability.

A third reason for the significant F values for the factor, panelists, may have been the extreme variation in the fabric samples evaluated. The range of fabric samples used covered the entire range of fabrics that are found in apparel outerwear. They ranged from silk broadcloth to wool suiting to bulky sweater knit fabric. If a more homogeneous group had been selected for the evaluation the variation in scores might have been lower.

The sum of squares in the analysis of variance tables for the panel shows the error attributed to the factor, panelists, is low compared to the error of the factor, fabric samples or the significant interactions. This factor supports panel reliability.

Correlation between Sensory Evaluation and Instrumental Measurment

The results of the instrumental measurements for the physical properties are listed in Appendix 7. The instrumental measurement values were correlated with the overall mean scores for the related properties that are given in Appendix 5.

Surface Friction

The correlation between the sensory evaluation scores and instrumental measurement of surface friction was examined by estimating association with the linear regression line. Two instrumental measurements were studied, coefficient of static friction and coefficient of kinetic friction.

The coefficient of kinetic friction was measured as the amount of force required to keep a cloth-covered sled moving over the fabric surface. A linear association was not demonstrated between the sensory scores and the values for the coefficient of kinetic friction. The correlation coefficient was approximately -0.20. The reason for this finding may have been the effect of the fabric specimen size on the panelists' evaluations. The 15-cm-width may not have been sufficient to allow the panelist to keep their hand sliding long enough to obtain a good assessment of kinetic friction.

The coefficient of static friction was measured as the amount of force required to start a cloth-covered sled sliding over the fabric surface. The sensory scores and the values for the coefficient of static friction are plotted in Figure 15. The plot

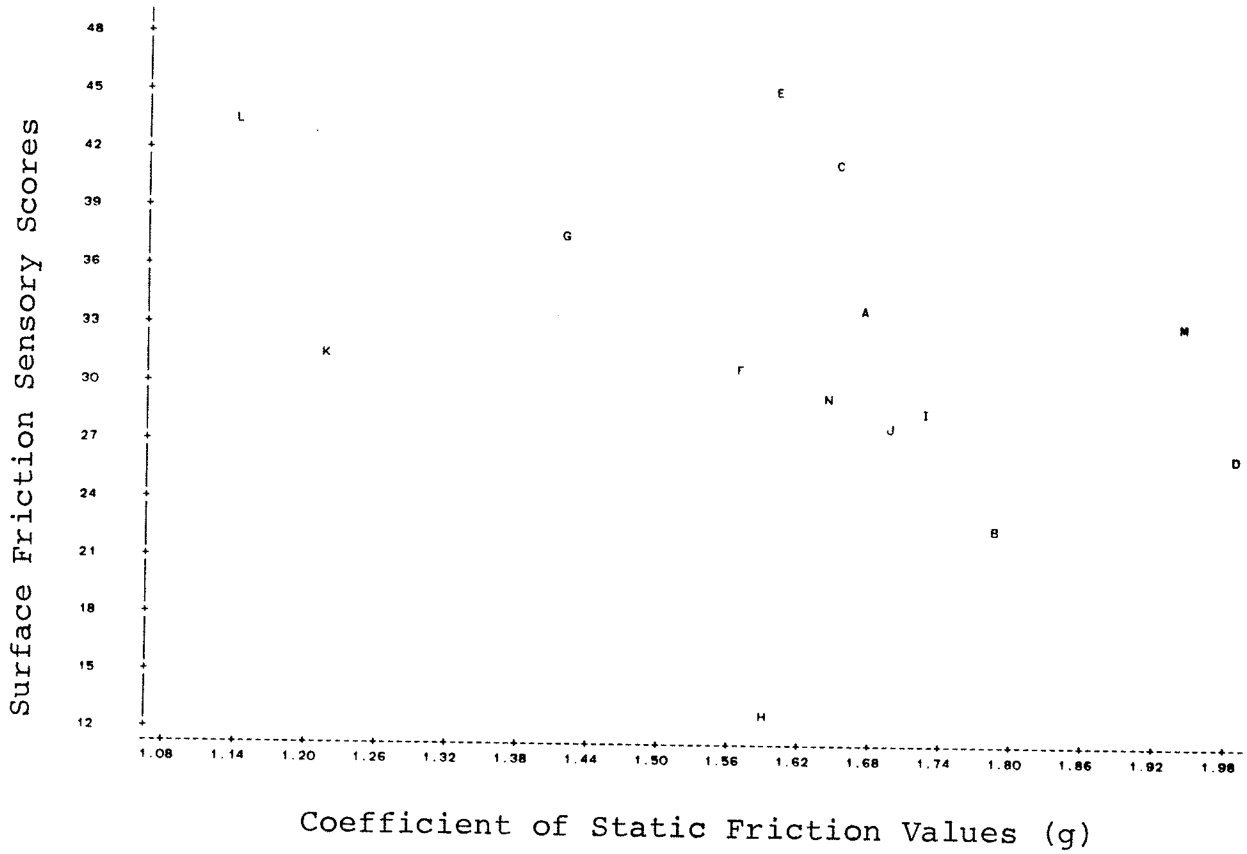


Figure 15. Plot of Surface Friction Sensory Scores and Coefficient of Static Friction Values

illustrates a poor association of the sensory scores and instrumental values. The correlation coefficient obtained for the linear relation was -0.39.

Overall, the instrumental measurement appeared to have a poor association with the sensory evaluation. The panelists may have been able to assess the ridges, bumps and fuzziness that give resistance to motion of the hand over the surface. If each occurrence influenced hand motion, the nonuniformity may have had an additive effect on the score. On the other hand, the instrument measurement involved pulling a 200 g cloth-covered sled across the fabric surface. In this case, the surface characteristics, such as ridges, bumps and fuzziness, were probably masked. The sled appeared to ride on the top of the discontinuities, and unlike the panelist's hand did not evaluate each discontinuity. For example, fabric samples L and K had uneven/bumpy contours which the panelists assessed as rough but the instrument measured smooth. The disparity of the two measures resulted in a negative value for the correlation coefficient.

In addition, the stretchiness of the fabric samples which was hypothesized to have influenced the sensory perception, would have had a greater influence in the case of the instrumental evaluation. It would be greater because of higher pressure associated with the instrumental measurement.

Compressibility

The correlation between the sensory scores and instrumental measurement of compressibility was examined by estimating association with the linear regression line. To obtain a good fit to a linear relation between the sensory and instrumental scores, the instrumental values for compression required transformation to the logarithmic value. The association obtained between the sensory scores and the logarithmic values for instrumental compression values is shown in Figure 16. The plot illustrates a good relation of the sensory scores with the logarithmic compression values (taken at a pressure of 0.7 kPa). The correlation coefficient obtained was 0.95.

As the instrumental value for compression of the fabric samples increased, there was a corresponding increase in the compression by the panel. Results for Tukey's test, given in the previous section, grouped the sensory scores for certain fabric samples.

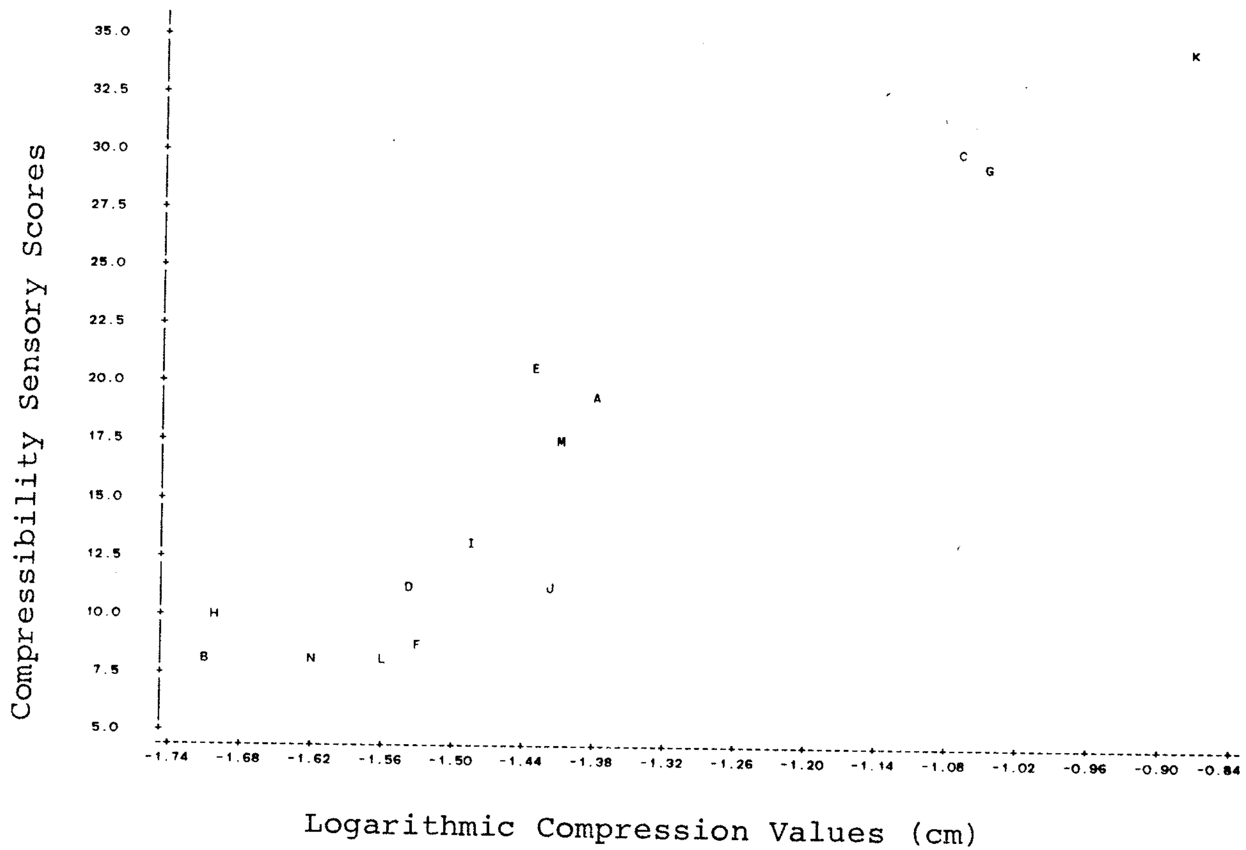


Figure 16. Plot of Compressibility Sensory Scores and Compression Values.

Similar groupings of fabric samples also occurred in the results obtained by the instrumental measurement. One reason for this result would be that the mechanisms to evaluation the fabric samples by both sensory and instrumental measurements were similar. The instrumental method involved lowering an anvil onto the fabric under controlled pressure. The sensory method involved pressing down on the fabric to a certain pressure with the full length of the fingers.

The need for the logarithmic transformation of the compression values was a reflection of the limited sensitivity of the panelists to discern differences. At the low (noncompressible) end of the scale, there appeared to be a limit to the panelist's ability to discern compression differences.

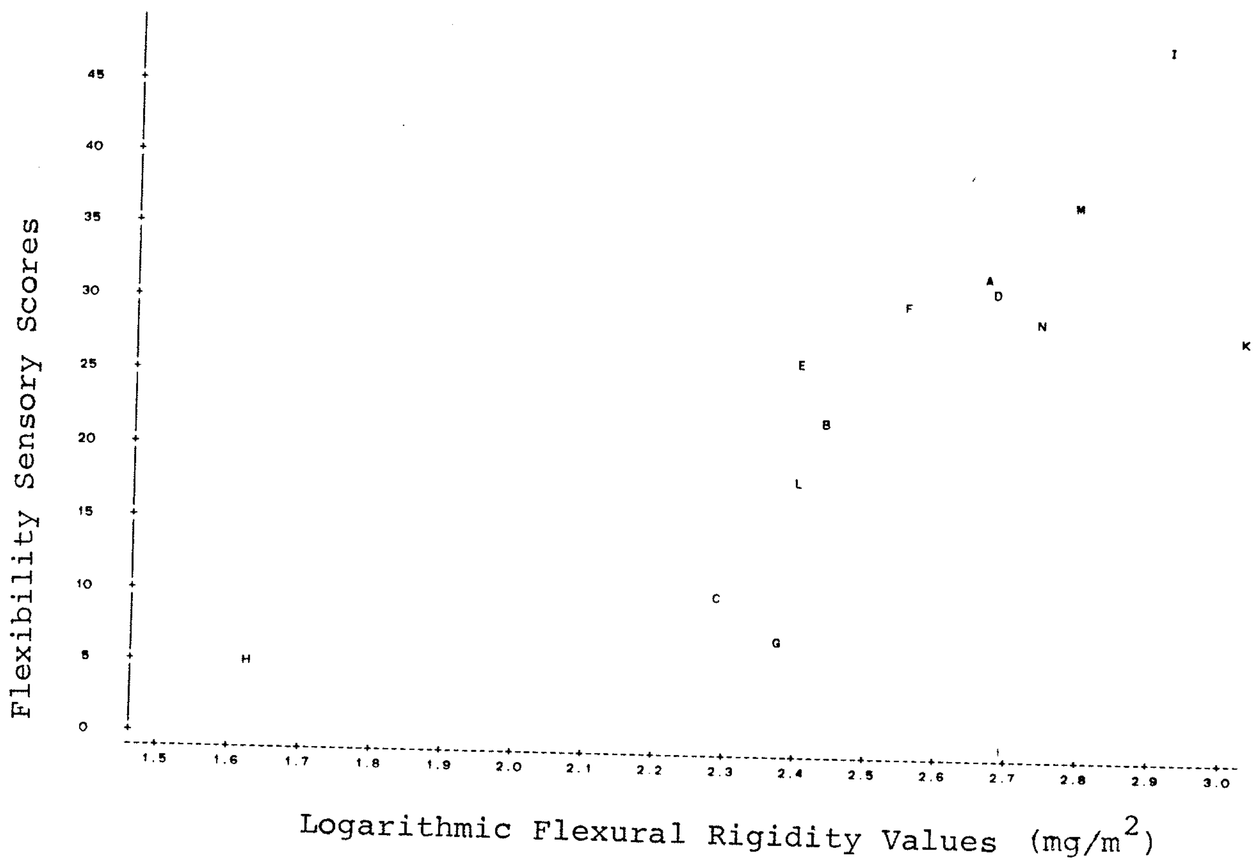
Flexibility

The correlation between the sensory scores and instrumental measurements for flexibility was examined by estimating association with the linear regression line. Two instrumental measurements were studied, bending length and flexural rigidity.

Bending length is a measure of the interaction between fabric weight and stiffness as shown by the way in which a fabric bends under its own weight. It is said to be related to the quality of drape. A good linear association was not demonstrated between the sensory results and the values for bending length. The correlation coefficient was approximately 0.70. The reason for this result may have been the influence of variations in the weight and thickness of the fabrics on the panelist evaluation.

The other method examined, flexural rigidity is a measure of resistance to bending by external forces. It is said to be related to the quality of stiffness appreciated by touch. The flexural rigidity measurement takes fabric weight into account, while bending length does not. To obtain a good fit to a linear relation between the sensory and instrumental scores, the instrumental measurement values required transformation to the logarithmic value. The sensory scores and the logarithmic values for flexural rigidity are plotted in Figure 17. The plot shows the relation of the sensory scores with the flexural rigidity values. The correlation coefficient obtained was 0.80.

When the panel scores indicated an increase in the



Note: 1 observation hidden

Figure 17. Plot of Flexibility Sensory Scores and Flexural Rigidity Values

resistance to deformation, there was a related increase in the logarithm of the flexural rigidity values. Knit fabric samples, however, were assessed differently by the panel than by the instrument. (Refer to Figure 17.) The knit structure of the fabric samples, such as C, E, G, H, and K, were perceived to be less stiff by the panel than was indicated by the flexural rigidity measurement. The groupings from the Tukey's test for the sensory scores were similar to the groupings of the instrumental measurement values.

The need for the logarithmic transformation of the flexibility values indicated an influence of the fabrics samples on the scores given by the panelists. At the low (limp) end of the scale, the flexural rigidity values increased but the panelists scores did not indicate a similar increase. This suggests low sensitivity of the sensory evaluation of limp fabrics.

Thickness

The correlation between the sensory evaluation and instrumental measurement for thickness was examined by estimating association with the linear regression line. The sensory scores and the values for instrumental thickness measurement are plotted in Figure 18. The plot illustrates a good association of the sensory results and the instrumental measurement values. The correlation coefficient obtained was 0.96.

As the panel evaluated an increase in the magnitude of the physical property, thickness, there was a corresponding increase in the instrumental values for thickness. The instrumental measurements grouped the fabric samples similarly to the groupings that resulted in Tukey's test, except for fabric samples E and L. (Refer to Figure 18.) The reason may have been due to the fabric structures fabric sample E was a jacquard double knit and fabric sample L contained a novelty yarn, which had raised surfaces. It is probable that the amount of compression obtained under the pressure of the anvil of the compressometer was influenced strongly by the projecting sections of the fabrics whereas the panelists appeared to be influenced by the thinner sections of the fabric samples.

Weight

The correlation between the sensory scores and

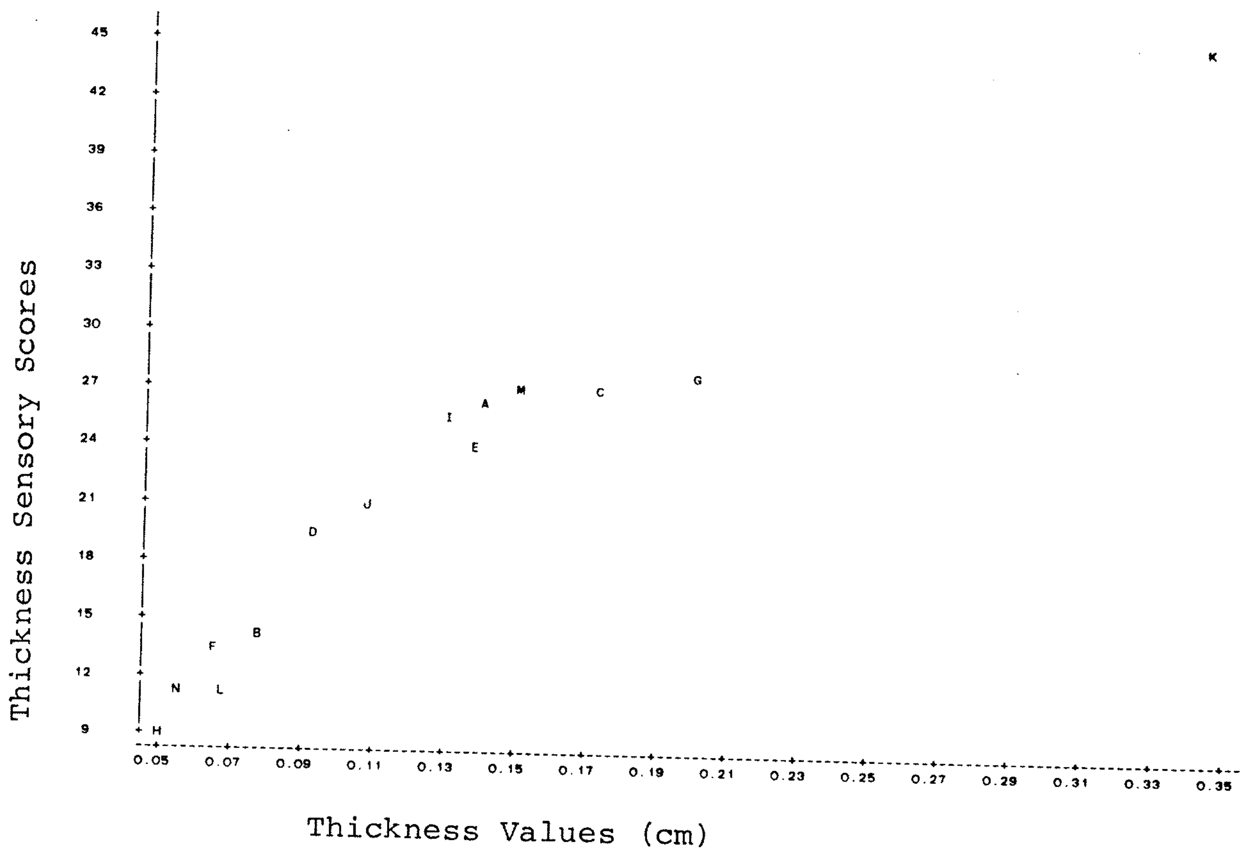


Figure 18. Plot of Thickness Sensory Scores and Thickness Values.

instrumental measurements for weight was examined by estimating association with the linear regression line. To obtain a good fit to a linear relation between the sensory and instrumental measurement values, the sensory scores for weight required transformation to logarithmic value. The logarithm for sensory scores and the values for instrumentally obtained weight are plotted in Figure 19. The plot shows a good association of the sensory and instrumental weight values. The correlation coefficient obtained was 0.98.

There was a similar increase in the logarithm of the sensory evaluation of weight for the fabric samples and the instrumentally measured weight. The knit fabric samples, such as fabric samples G and K, were perceived as lighter than the values given by the instrumental measurements.

The need for the logarithmic transformation of the sensory scores indicated an influence of the fabric samples on the scores given by the panelists. At the low (light) end of the scale the weight increased but the panelists scores did not show a similar increase. At the high (heavy) end of the scale there was a similar effect to a small degree. When the

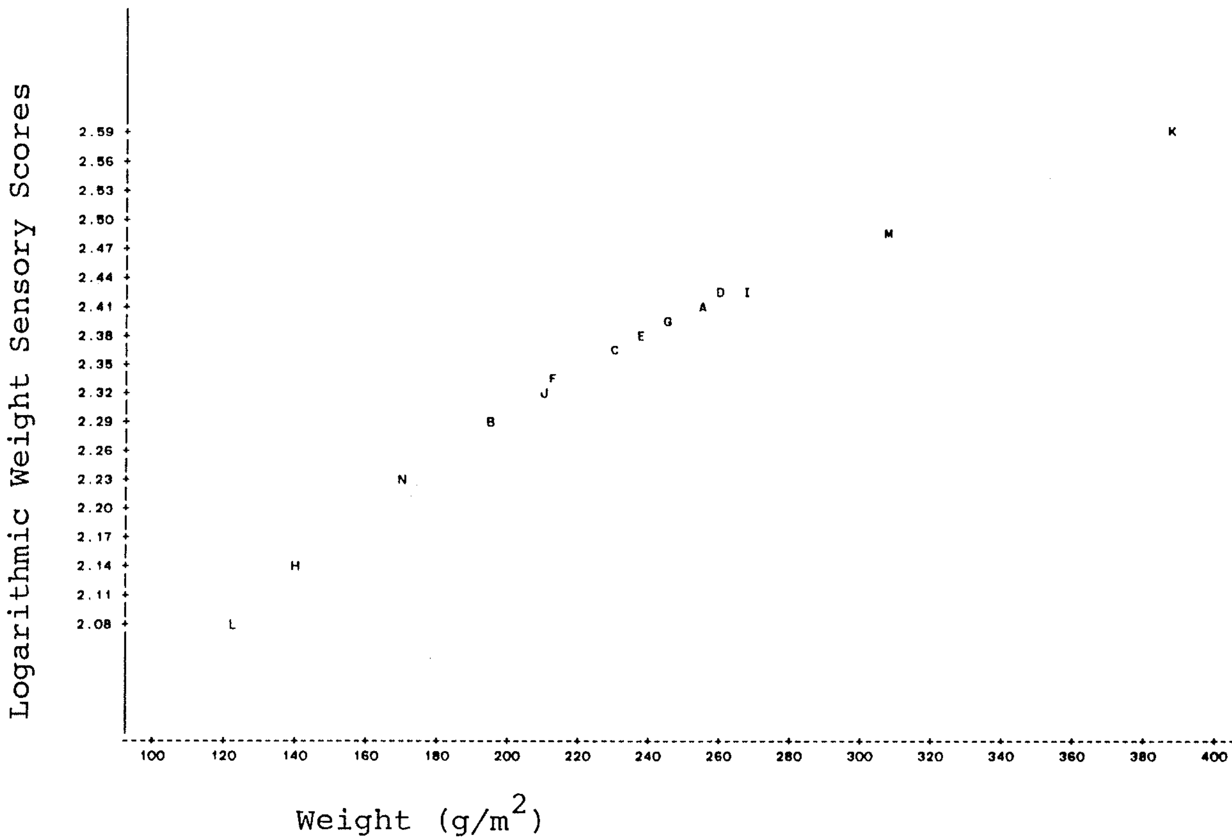


Figure 19. Plot of Weight Sensory Scores and Weight Values.

logarithmic values are used this nonlinear association is reduced. The panel appeared to be able to assess weight in the middle range with greater sensitivity.

Summary

The correlation coefficients between the sensory scores and instrumental measurement values show that there were good associations for some properties. For compressibility, thickness, and weight, there were good associations as shown by high correlation coefficients. There appeared to be a limit to the sensitivity of the panelists to discern between the fabric samples at the lower ends of the scales.

The correlation coefficient for the property, flexibility, was lower than that for compressibility, thickness, and weight. The wide variation in the knit fabric structures may have caused the lower association.

The association for the property, surface friction, was poor, the correlation coefficient being low (-0.39). Some fabric samples that were given high scores by the panelists were given low measurement values in the instrumental test. This may be a reflection of inherent problems in the instrumental test method used for surface friction.

Fabric Hand Profile for Each Fabric Sample

In the foods area, a texture profile is prepared from the sensory scores. It provides a record of the texture complex in terms of the textural characteristics, showing the degree of each characteristic present and the order of appearance of the sensory stimuli. As the system developed for measurement of the tactile complex of a fabric in terms of its physical properties and the degree of each present, a profile similar to that used in the foods area can be prepared. The profile prepared can be used as a record of the results of the sensory evaluation and as a representation of the hand of a fabric sample.

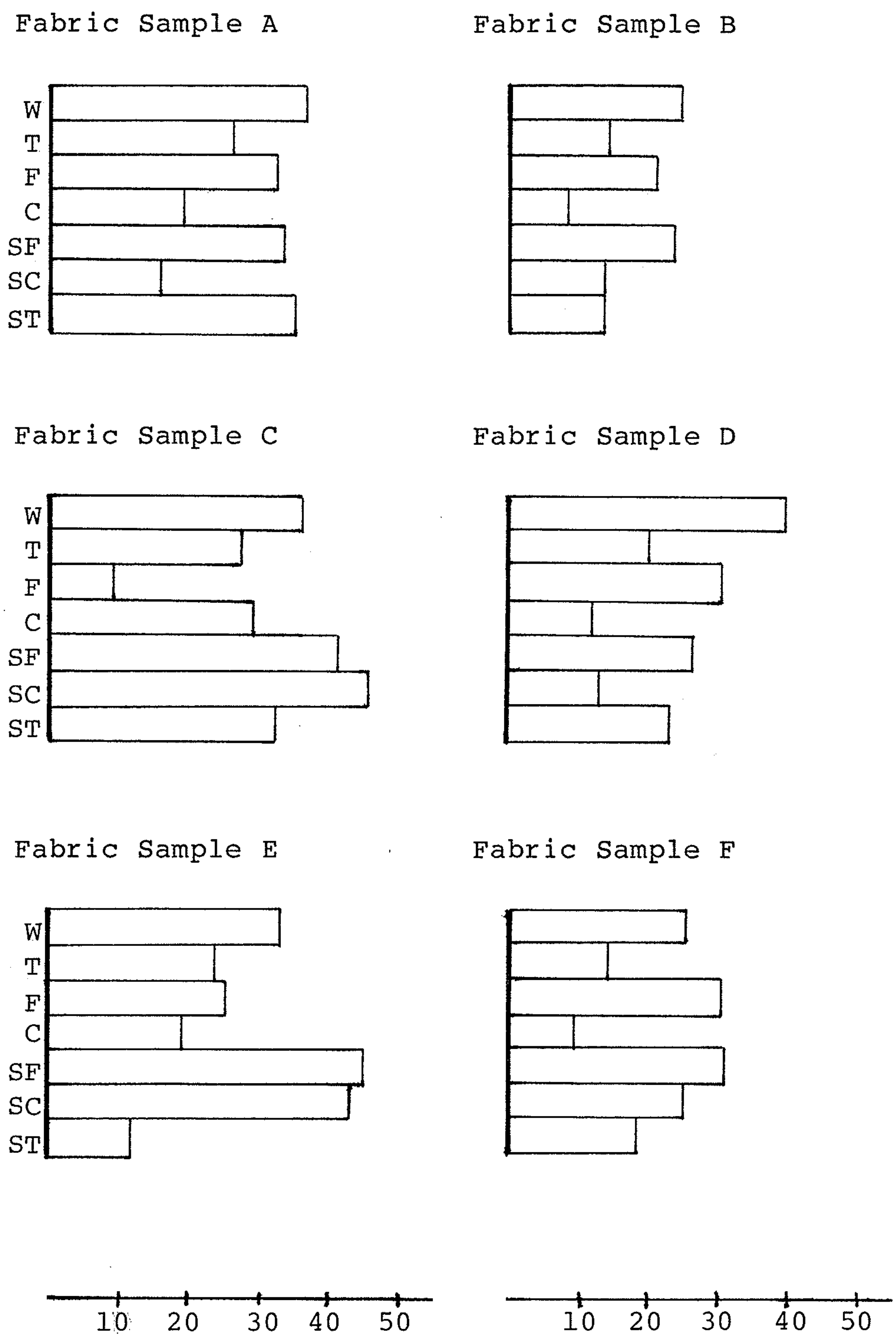
Development of a profile allows the quantitative values of several physical properties in a variety of fabric samples to be depicted in a visual manner by means of bar graphs. This visual record or profile allows personnel to compare property differences among the fabric samples or to quickly assess the magnitude and extent of property differences of a single fabric.

To demonstrate further application of the Texture Profile method,profiles for the fabric samples evaluated in the test trial were constructed. Each property in the profile is depicted by a bar graph. The magnitude of the bars represents the mean score for an individual property.

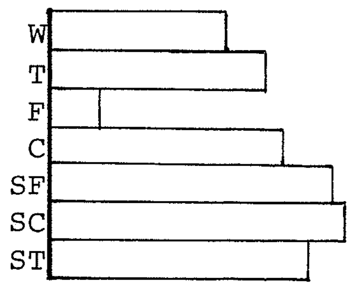
The profiles are constructed in a graph with the properties associated with the vertical axis. The codes associated with this axis are:

1) ST = Surface Texture,
2) SC = Surface Contour,
3) SF = Surface Friction,
4) C = Compressibility,
5) F = Flexibility,
6) T = Thickness, and
7) W = Weight.

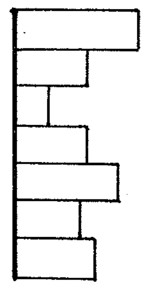
The horizontal axis represents the sensory scores and is labelled with numbers that represent the magnitude of the sensory evaluation scores.


Fabric Sample A
Fabric Sample B
W
T
F
C
SF
SC
ST
Fabric Sample C
Fabric Sample D
W
T
F
C
SF
SC
ST
Fabric Sample E
Fabric Sample F
W
T
F
C
SF
SC
ST
10 20 30 40 50
10 20 30 40 50

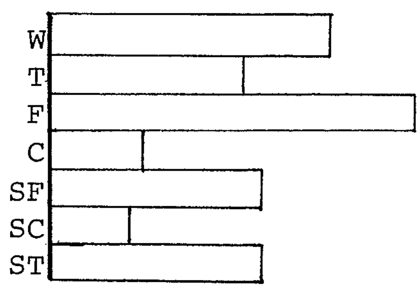
Fabric Sample G



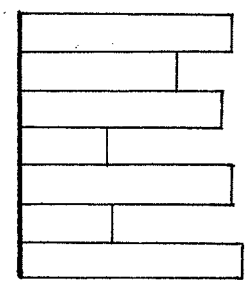
Fabric Sample H



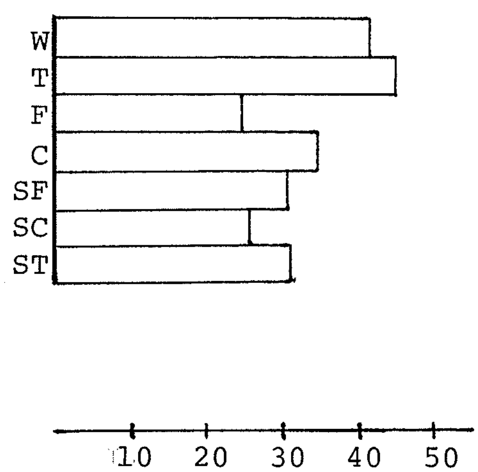
Fabric Sample I



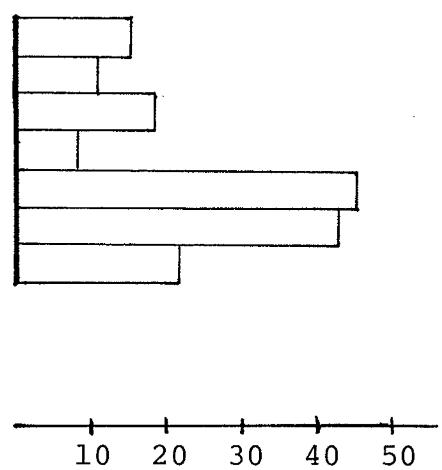
Fabric Sample J



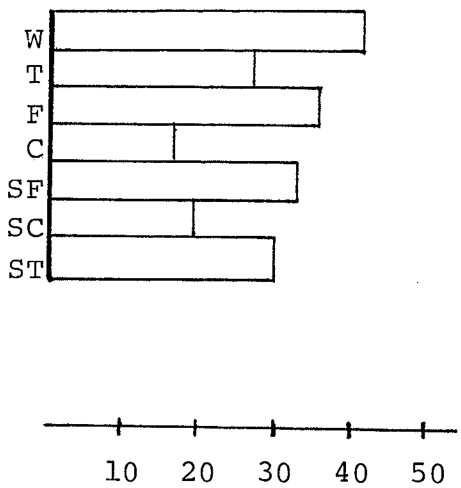
Fabric Sample K



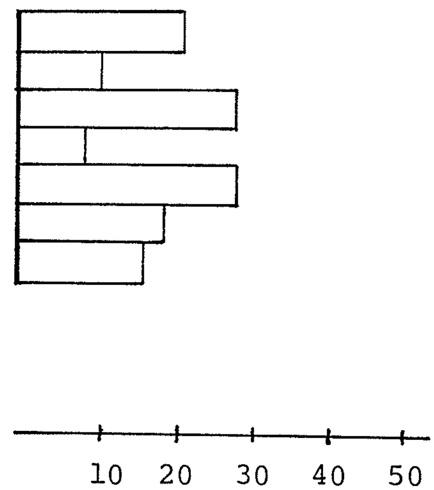
Fabric Sample L



Fabric Sample M



Fabric Sample N



CHAPTER FIVE

SUMMARY AND RECOMMENDATIONS

The purpose of the present study was to develop and evaluate a method of assessing fabric hand similar to the basic pronciples of the Texture Profile method for foods. The method was developed with evaluation procedures that contained commonly understood terminology, standardized handling techniques, and rating scales with reference samples. Procedures were developed to evaluate the major characteristcis related to fabric hand: surface texture, surface contour, surface friction, compressibility, flexibility, thickness, and weight.

Summary of Results

Panels and group discussions were employed to develop the standards and procedures. The development was divided into three stages: collecting descriptive words, developing and refining terminology and handling techniques, and developing the scales with reference standards. The developed method consisted of evaluation procedures for each of the fabric hand properties studied. The procedures were:

a) Surface Texture was assessed by grazing the surface with the fingers and judged by the largest amount of protruding fibre ends, ranging from nonfuzzy to fuzzy.

b) Surface Contour was assessed by a similar technique and judged by the largest amount of deviation from a plane, ranging from flat/even to bumpy/uneven.

c) Surface Friction was also assessed in a similar manner and judged by the largest amount of resistance offered to the hand motion, ranging from smooth to rough.

d) Compressibility was judged by applying a certain amount of pressure with the fingers and the assessment given ranged from noncompressible to compressible.

e) Flexibility was judged by folding the fabric specimen in half and applying pressure at the fold to evaluate the resistance offered and the assessment ranged from limp to stiff.

f) Thickness was assessed by holding the fabric sample between the thumb and finger while moving the thumb gently over the fabric edge and the judgment ranged from thin to thick.

h) Weight was assessed by placing the entire fabric specimen in the hand and making a judgment ranging from light to heavy.

Development of these procedures and standards constituted achievement of the first objective of the study.

To fulfill objective two, the method was subjected to a test trial. In this trial, a panel was trained to use the developed procedures. When trained, the panel evaluated a group of apparel fabrics. The fabrics were chosen to represent a range of each physical property.

Training of the panel allowed the panelists to become acquainted with the evaluation procedures and to assess fabric samples in an objective meanner that reduced the effects of personal preference and other influential factors. By increasing the objectivity of the sensory method for assessing fabric hand, the panelists would be able to give more reliable results.

During the test trial, the reliability of each panelist was examined by analysis of variance. This analysis was accomplished by examining two factors: fabric samples and replications. The difference in fabric samples scores was reflected by a significant fabric samples factor. The ability of the panelists to have similar scores between replications was indicated when the replications factor was nonsignificant.

Most of the panelists gave scores that were reliable. The analysis showed that there were significant differences for the fabric samples and nonsignificant differences for the replications in almost all cases. For properties, surface texture, flexibility, and weight, the scores of one panelist showed failure to discern the different property levels among the fabric samples. For properties, surface texture, surface contour, compressibility, flexibility, thickness, and weight, one or two (in one case, three) panelists did not have similar scores for the replications.

When panelist scores did not have reliability, their scores were eliminated from that property for evaluation of panel reliability. Panel reliability was examined by analysis of variance. The total variance was divided into three factors: panelists, fabric samples, and replications; and two interactions: panelists by fabric samples, and panelists by replications. The factor, fabric samples, was found to be significant for each physical property indicating that the panel scores reflected the differences in the property levels of the fabric samples. This would indicate reliability because the fabric samples with different property levels were selected for the test trial.

The factor, replications, were nonsignificant for each property, indicating the scores assessed by the panel were similar between the repliactions, suggesting panel reliability.

The factor, panelists, was significantly different for some physical properties, such as surface contour, surface friction, flexibility, thickness, and weight. The panelists factor was nonsignificant for surface texture and compressibility. Ideally, a nonsignificant difference indicates panelists were assessing the fabric samples similarly. The reasons for the significant differences may have been a result of:

a) differences in the placement of scores on the scale may reflect panelist perception of the line scale and a tendency for some to give consistently higher or lower scores,

b) an insufficient amount of training for some panelists and/or inability to deal with the sensory techniques,

c) the extreme variation in the fabric samples used in the test trial.

The significant difference for the panelists factor was not considered to detract from the reliability of the method because the sum of squares in the analysis of variance for the panel showed that other factors, fabric samples and panelists by fabric samples interaction, explained much more of the variation than the factor, panelists. The difference among the panelists' scores is probably a reflection of human variability that cannot be eliminated from the procedures.

The results showed nonsignificant interactions for panelists by replications. This indicated that there was a similarity in how the panelists assessed the fabric samples between the replications.

There was a significant interaction for panelists by fabric samples for all physical properties except for compressibility. This indicated that there may have been a difference in how the panelists assessed the property level depending on the fabric sample being evaluated.

Observations of differences in the fabric samples were used to explain how the fabric factors might influenced the panelists' assessments of the different properties. For the surface characteristics, the panelists appeared to have been affected by the yarn and/or fabric structures used in the fabric samples. Compressibility and thickness may have been influenced by the fabric thickness, density, and fabric structure. Flexibility may have been affected by the degree of mobility of yarns within the structures, fabric thickness, and ability of the fabric to compress at the bend during sensory evaluation. Weight appeared to have been influenced by the bulkiness of the fabric specimen.

Tukey's test was used to examine scores for each property. Adjacent scores for some fabric samples were not found to be significantly different using this test. This was an indication that there was a limit of how small a property difference could be discerned by the panel.

The correlations between the sensory evaluations and instrumental measurements were examined by estimating association with the linear regression line. Transformations of the data were examined if the results did not prove a high correlation. To obtain a good fit to a linear relation between the sensory scores and instrumental measures for compressibility and flexibility required transformation of the instrumental measurement to the logarithmic value, and for weight required transformation of the sensory scores to the logarithmic value. These transformations indicated that panel sensitivity for distinguishing changes in property levels was reduced at the lower end of the scales.

The correlations between the sensory evaluation and instrumental measurement showed good linear associations for weight, thickness, flexibility, and compressibility. The good correlations for these physical properties suggest that the instrumental measurement may give an indication of the sensory response for the fabric samples. The correlation between the sensory evaluation and instrumental measurement for surface friction did not demonstrate a linear association. Objective three, to determine the relation between the sensory evaluation and instrumental measurements, was achieved for the properties, compressibility, flexibility, thickness, and weight, but was not achieved for surface friction.

Application of Research

As the sensory procedures were found to be reliable in measuring the hand of a group of apparel fabrics, the panel results were shown to be effective in the development of fabric hand profiles. These were constructed for each fabric sample. In this way, the difference in property levels among the apparel fabrics can be quickly ascertained. These profiles can be applied in quality control procedures used in the manufacture of textile products, in development and improvement of textile products, and in providing knowledge about fabric hand.

As a tool for quality control in manufacturing of textile products, fabric hand profiles would be particularly useful as reference standards for comparison. Such standards of comparison could be based on consumer preference, comfort, tailorability, or other characteristics where hand is important and could be used in selecting fabrics to meet desired criteria.

The application for development and improvement of textile products can be demonstrated by the profiles for fabric samples I and J. Fabric sample I, a woven wool blend bonded to a tricot knit, and fabric sample J, the same woven wool blend, show the differences that would result from the process of lamination. The process did not effect the surface characteristics or compression but did effect flexibility, thickness and weight. The degree of influence can be quickly ascertained from observation of the profiles.

The sensory method can be applied in providing knowledge about fabric hand for any group of textile products. In the present study, a variety of apparel fabrics were evaluated but the method can also be used in studying more homogeneous groups of fabrics, such as suiting fabrics or dress weight fabrics.

Recommendations for Further Study

The sensitivity of the panel and panelists needs to be studied. There appeared to be limitations in the ability of the panelists to discern small differences in the physical properties. Also, the sensitivity of the evaluations at the higher and lower intensities of the physical properties requires investigation. Information on the sensitivity of panelists to make the hand evaluations would be useful in the training of a panel and in knowing whether the panelists are or can use a given procedure.

The present study used fourteen fabric samples, a wider range of apparel fabrics needs to be studied. The present study shows that the evaluation method can be designed and used effectively but the conclusions that may be drawn are restricted to the group of apparel fabric used.

The structure of fabrics varied widely through having different fibres, yarns, weaves and knits, and finishes. There is a need for studies to look systematically into the factors that influence the physical properties related to fabric hand. Such studies would lead to better descriptions and measurements of fabric hand.

The correlations between the sensory evaluation and the instrumental measurement need further investigation. Different instrumental test methods need to be studies in comparison with the sensory evaluations. The single instrumental measurement studies in the present research showed that instrumental measurements can give an indication of the sensory response for some physical properties. Further study might yield prediction equations that would be precise enough for quality control and for product development and improvement studies.

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APPENDIXES

Appendix 1

A Short Explanation of the Concept of Fabric Hand and Review of Past Studies

The general description of fabric hand comes from the subjective assessment of a textile material obtained from the sense of touch. The actual description of hand that researchers have used has varied depending on the researcher's scope of interest. From the point of view of consumers, fabric hand is an important aesthetic factor and is used as a means to judge fabric desirability. For the textile technologists, fabric hand can provide information to help make decisions concerning various production processes.

There is a common starting point for defining hand from which the orientation can vary according to the investigator's interest. One main orientation is subjective assessment used to calculate consumer preference. The second main orientation is subjective assessment used to calculate a value for hand.

Even though there has been extensive work done on hand, further work is needed. There is still a need for an effective objective description of hand. In past studies, consumer preference has had a strong influence on results obtained. This has limited usefulness to the textile technologists. The description needs to be based on objective ways of measuring hand by participants doing the sensory evaluation. In other studies, focus has been on the selection of characteristics according to the physical properties that are important in consumer preference. Yet, the authors still relate the results back to consumer preference. Studies that eliminate personal preference should be done. Until personal preferences are eliminated the results of studies will fluctuate with changes in fashion, time, culture and other influential factors.

In sensory evaluation of food products, a useful method has been developed, called the Texture Profile method. The Profile Method is like an objective method of judging products which does not depend on personal preference or reserve a final judgment as to the quality. This method is being adapted for the evaluation of fabrics through standardized handling procedures and understanding of a common terminology.

The use of standardized handling procedures and terminology, increases the objectivity of the test method. The method eliminates the influence of personal preference -- panelist's personal opinions of the fabrics will not be asked. The procedures used in the fabric hand method are to provide a more effective description of hand.

Up to this point, the handling techniques, definition of the properties and associated descriptive terms and scales with points of reference have been standardized. It is the purpose of this panel to use these in the evaluation method.

Appendix 2

An Brief Explanation of the Method Used to Outline the General Procedures

The training sessions include instructions on the definitions of the physical properties and descriptive terms, the explanation and demonstration of the handling procedures and how to use the scales. One purpose of the training sessions is to bring forward any difficulties that a person may be having with the method. Open discussions are encouraged so that everyone is familiar with the method and the task that is asked of them. Panelists will be able to practice on samples, to make sure they are comfortable with the method.

The general outline of the method is that the panel is to be trained in the use of the handling procedures, related terminology and rating procedures. Following the training sessions, the testing sessions will take place. The trained panelists will evaluate various fabrics using the evaluation method. The results will be recorded on scales for each physical property. The handling procedures will cover the sensory evaluation of the physical properties that have been examined in the past and related to fabric hand. The physical properties examined will be flexibility, compressibility, thickness, weight, surface friction and surface contour. The scales used to record the results are semi-structured with points of reference. The points of reference have standard samples assigned to them. The physical properties, descriptive terms and reference samples will then be defined for the panel. (Refer to Tables 9 - 12.)

Appendix 3

The Sensory Evaluation Ballots

In Appendix 3, the sensory evaluation ballots used in the study are listed. The information about the reference standards are given in Tables 11 and 12.

Figure 20. Sensory Evaluation Ballot for Surface Texture.

Date:

Name:

SURFACE TEXTURE

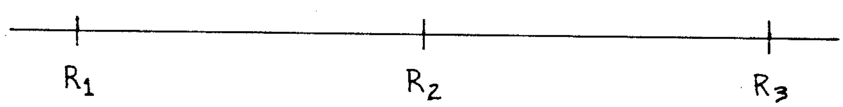
Surface texture is the amount of fibre ends protruding from the surface of the fabric sample. The associated descriptive terms are:

fuzzy -- the fabric's surface has protruding ends, and

nonfuzzy -- the fabric's surface does not have protruding ends.

For surface texture, the fabric sample is placed flat on the table. Using the whole length of the fingers, graze the surface with very little pressure, in the warp and filling directions. Note the largest amount of fuzziness the surface has.

The line scale is:



nonfuzzy fuzzy

In order, evaluate samples:

Figure 21. Sensory Evaluation Ballot for Surface Contour.

Date:

Name:

SURFACE CONTOUR

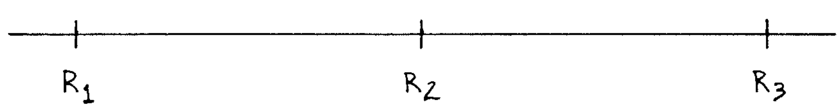
Surface contour is the amount the fabric's surface deviates from a plane. The associated descriptive terms are:

uneven/bumpy -- the fabric's surface follows a wavy line and does deviate from planeness, and

even/flat -- the fabric's surface follows a straight line and does not deviate from planeness.

For surface contour, the fabric sample is placed flat on the table. Using the whole length of the fingers, graze the surface with a little pressure, in the warp and filling directions. Note the largest amount of deviation the surface has from a straight line.

The line scale is:



even/flat uneven/bumpy

In order, evaluate samples:

Figure 22. Sensory Evaluation Ballot for Surface Friction.

Date:

Name:

SURFACE FRICTION

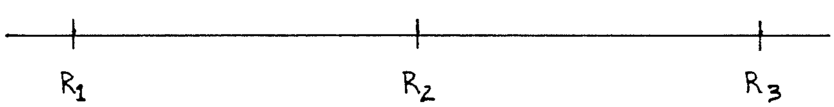
Surface friction is when the hand is made to slide over the fabric sample, the hand tends to stick, there is a resistance and force is required to keep the hand moving. The magnitude of this force indicates the level of friction between the hand and fabric surface. The associated descriptive terms are:

rough -- the hand sticks to the surface of the fabric sample, which offers resistance and force is required to keep the hand sliding, and

smooth -- the hand does not stick to the surface of the fabric sample, which offers little to no resistance and a low amount of force is required to keep the hand sliding.

For surface friction, the fabric sample is placed flat on the table. Using the top portion of the fingers, graze the surface with a little pressure, in the warp and filling directions. Note <u>largest</u> amount of resistance offered to the fingers by the fabric surface.

The line scale is:



smooth rough

In order, evaluate samples:

Figure 23. Sensory Evaluation Ballot for Compressibiltiy.

Date:

Name:

COMPRESSIBILITY

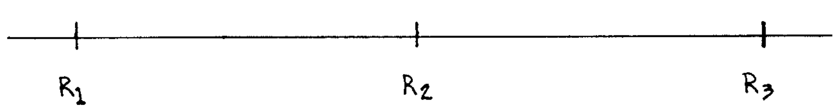
Compressibility is the ability for the fabric to reduce its thickness when compressed or squeezed. The associated descriptive terms are:

compressible -- the fabric sample decreases in thickness when pressure is applied, the fabric sample 'gives' easily when pressed, soft, and

noncompressible -- the fabric sample does not reduce in thickness when pressure is applied, there is no 'give' to the fabric when pressed, hard.

For compressibility, the fabric sample is placed flat on the table. Using the full length of the fingers, press down slowly on the fabric. The amount of pressure added is enough to displace a top loading balance by approximately 50 grams.

The line scale is:



noncompressible compressible

In order, evaluate samples:

Figure 24. Sensory Evaluation Ballot for Flexibility.

Date:

Name:

FLEXIBILITY

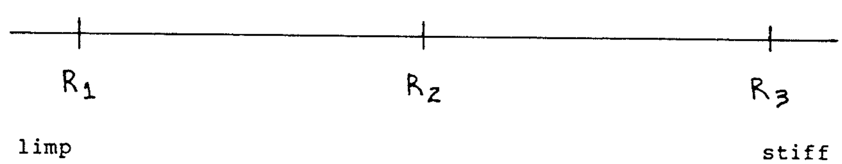
Flexibility is the amount of stiffness in the fabric sample. The stiffness is measured by the ease with which the fabric deforms or the resistance the fabric offers to deformation. The associated descriptive terms are:

stiff -- the fabric sample resists the deformation, and

limp -- the fabric sample does not resists the deformation.

For flexibility, the fabric sample is placed on the table. Gently fold the fabric sample is half across the warp yarns. The face of the fabric will be on the inside. Press down gently and slowly with the top portion of the fingers on the fold of the fabric, do not crease the fabric. The evaluation is made when the fingers are pressing down on the fabric and not when they are coming up.

The line scale is:



In order, evaluate samples:

Figure 25. Sensory Evaluation Ballot for Thickness.

Date:

Name:

THICKNESS

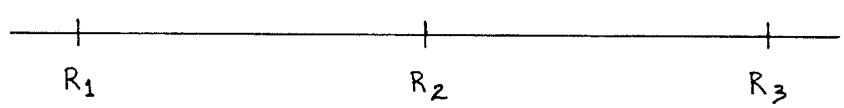
Thickness is the distance between the upper and lower surfaces of the fabric sample that the finger and thumb feels. The associated descriptive terms are:

thick -- the distance between the finger and thumb is great, and

thin -- the distance between the finger and thumb is small.

For thickness, the fabric sample is held between the finger and thumb along the edge. Moving the thumb gently over the edge of the fabric sample to evaluate the thickness. Gently refers to a slight pressure being added by the thumb as it moves over the fabric's edge.

The line scale is:



thin thick

In order, evaluate samples:

Figure 26. Sensory Evaluation Ballot for Weight.

Date:

Name:

WEIGHT

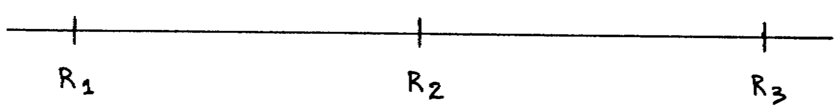
Weight is the heaviness of the fabric sample or the weight of the fabric sample. The associated descriptive terms are:

heavy -- the fabric sample has a large weight, and

light -- the fabric sample has a small weight.

For weight, the entire fabric sample is held in the palm of the hand and the hand is moved slightly up and down to feel the weight. There should be little to no overhang of the fabric sample.

The line scale is:



light heavy

In order, evaluate samples:

Appendix 4

The Sensory Data Collected During the Test Trial

Table 29. Sensory Data.
The code for the data listed is:
1) OBS = observations
2) PANELIST = panelists
3) FABRIC = fabric samples
4) REP = replications
5) SURTEX = surface texture
6) SURCON = surface contour
7) SURFRI = surface friction
8) COMPRES = compresibility
9) FLEX = flexibility
10) THICK = thickness
11) WEIGHT = weight

OBS	PANELIST	FABRIC	REP	SURTEX	SURCON	SURFRI	COMPRES	FLEX	THICK	WEIGHT
1	A	A	1	29.0	23.0	29.0	15.5	22.5	26.0	32.0
2	A	B	1	13.0	14.0	26.0	7.5	21.0	12.0	28.0
3	A	C	1	18.5	55.0	35.0	28.0	11.0	25.0	29.5
4	A	D	1	21.0	24.0	20.0	19.0	29.0	13.5	45.0
5	A	E	1	12.0	47.0	29.0	24.0	17.0	18.0	27.0
6	A	F	1	14.5	17.5	22.0	10.0	29.0	12.5	33.0
7	A	G	1	40.0	47.0	36.0	27.0	8.0	26.5	6.0
8	A	H	1	8.0	7.0	10.0	11.0	2.0	6.0	14.0
9	A	I	1	26.0	13.0	15.0	11.0	44.5	23.0	33.0
10	A	J	1	25.0	11.0	23.5	11.0	21.0	16.0	30.0
11	A	K	1	34.0	34.0	25.0	32.5	26.5	38.5	52.5
12	A	L	1	12.0	47.0	39.0	13.0	12.0	8.0	10.0
13	A	M	1	24.0	19.0	42.0	18.0	25.0	20.0	55.5
14	A	N	1	12.5	18.0	28.0	8.0	19.0	13.0	28.5
15	A	A	2	43.0	14.5	26.5	19.0	33.5	25.0	37.0
16	A	B	2	13.0	14.0	26.0	7.5	31.0	12.0	28.0
17	A	C	2	18.5	55.0	35.0	28.0	11.5	25.0	29.5
18	A	D	2	29.0	16.0	23.5	15.0	36.5	13.5	38.0
19	A	E	2	11.0	24.0	36.0	19.0	16.0	15.0	27.0
20	A	F	2	18.0	29.0	22.5	9.0	21.0	13.0	17.0
21	A	G	2	28.0	49.0	41.0	20.0	11.0	24.0	23.0
22	A	H	2	9.0	6.0	12.0	9.5	5.0	7.5	8.5
23	A	I	2	33.0	11.0	17.0	13.0	37.5	24.0	34.5
24	A	J	2	34.5	9.5	14.5	12.5	27.0	20.0	20.0
25	A	K	2	37.0	24.0	35.5	31.0	23.5	38.0	42.5
26	A	L	2	9.0	41.0	41.0	7.0	18.0	10.0	12.0
27	A	M	2	37.0	20.0	23.5	17.0	40.5	24.0	31.0
28	A	N	2	14.0	16.0	29.5	9.0	26.0	9.0	16.0
29	B	A	1	29.0	13.0	41.0	20.0	35.0	27.0	39.0
30	B	B	1	12.0	24.0	12.0	10.5	20.0	14.5	28.0
31	B	C	1	30.5	56.0	48.0	32.5	14.0	21.0	33.0
32	B	D	1	18.0	20.0	26.5	17.0	30.0	18.0	36.5
33	B	E	1	8.0	44.0	50.0	25.0	30.0	20.5	25.0
34	B	F	1	8.0	17.0	35.0	15.0	35.5	12.0	13.0
35	B	G	1	40.0	36.0	43.0	29.0	2.5	26.0	24.0
36	B	H	1	17.0	7.0	6.0	6.0	4.0	7.0	12.0
37	B	I	1	25.0	8.0	28.0	12.0	54.0	22.0	33.0
38	B	J	1	26.0	11.0	27.5	10.5	34.0	17.0	32.0
39	B	K	1	40.0	28.5	50.0	31.0	33.0	43.5	52.0
40	B	L	1	32.0	29.0	46.0	6.5	35.5	13.0	8.5
41	B	M	1	15.0	29.0	29.0	21.0	50.0	28.5	41.5
42	B	N	1	8.0	11.0	26.0	7.0	31.5	9.0	18.5
43	B	A	2	33.0	23.0	42.0	11.5	31.0	21.0	29.0
44	B	B	2	25.0	15.0	34.0	8.0	24.5	13.0	22.0
45	B	C	2	47.5	33.0	48.0	33.5	2.0	26.0	34.0
46	B	D	2	30.0	22.0	39.0	10.0	33.0	23.5	46.5
47	B	E	2	51.5	36.0	45.0	19.0	26.0	22.0	31.5
48	B	F	2	14.0	23.0	31.5	6.0	32.5	15.5	25.5
49	B	G	2	35.5	44.0	44.5	29.5	2.5	20.0	19.0
50	B	H	2	22.0	7.0	7.0	8.0	2.0	8.5	10.5
51	B	I	2	27.5	18.0	29.5	10.0	56.0	28.5	24.5
52	B	J	2	27.0	25.0	32.0	16.5	23.5	18.0	24.0
53	B	K	2	40.5	34.0	41.0	35.0	29.5	50.0	54.5
54	B	L	2	20.5	30.5	47.0	9.0	24.5	12.5	21.0
55	B	M	2	35.0	28.0	35.0	11.0	38.0	28.0	33.0
56	B	N	2	24.5	21.0	34.0	9.0	35.0	8.0	33.5

Sensory Data con't.

OBS	PANELIST	FABRIC	REP	SURTEX	SURCON	SURFRI	COMPRES	FLEX	THICK	WEIGHT
57	C	A	1	46.0	13.0	36.0	25.5	38.0	26.0	47.0
58	C	B	1	8.0	7.0	16.0	7.5	27.0	13.0	18.0
59	C	C	1	39.0	49.5	48.0	29.0	10.0	29.0	40.5
60	C	D	1	28.0	8.0	16.5	11.0	29.5	21.0	36.5
61	C	E	1	9.5	34.0	45.0	13.0	28.0	21.0	31.0
62	C	F	1	11.0	26.5	30.0	10.5	35.0	11.0	22.5
63	C	G	1	28.0	30.5	43.0	29.0	7.0	30.0	32.0
64	C	H	1	7.0	7.0	9.5	8.0	6.5	12.5	12.5
65	C	I	1	28.0	10.5	22.0	13.0	49.5	26.5	37.0
66	C	J	1	25.5	12.0	32.0	11.0	14.0	24.0	24.5
67	C	K	1	28.0	16.0	39.0	40.5	25.0	46.0	48.5
68	C	L	1	13.0	52.0	43.5	10.0	26.0	11.0	12.0
69	C	M	1	46.0	12.0	34.5	18.5	43.0	25.0	52.0
70	C	N	1	8.0	19.0	28.5	9.0	27.5	9.0	19.0
71	C	A	2	40.0	10.5	40.5	28.0	32.5	26.5	35.0
72	C	B	2	10.5	7.5	19.0	9.0	25.5	12.0	23.5
73	C	C	2	34.0	34.5	45.0	28.5	10.0	28.5	32.5
74	C	D	2	18.0	10.0	36.0	15.5	31.0	16.0	32.0
75	C	E	2	8.5	32.5	49.0	24.0	28.0	20.0	30.0
76	C	F	2	13.0	16.0	33.0	9.0	34.5	12.0	18.0
77	C	G	2	26.0	31.0	36.0	29.0	15.0	26.5	27.0
78	C	H	2	8.0	6.5	23.5	12.5	6.5	8.0	10.0
79	C	I	2	29.0	11.0	36.5	25.0	52.0	21.0	40.0
80	C	J	2	27.0	8.0	32.0	11.0	30.0	23.0	17.0
81	C	K	2	25.0	27.0	41.0	37.0	28.5	43.0	46.0
82	C	L	2	9.5	40.0	50.5	8.0	14.0	10.5	10.0
83	C	M	2	30.0	14.0	32.0	28.5	38.0	29.0	47.5
84	C	N	2	11.5	14.0	25.0	8.5	31.5	11.0	14.0
85	D	A	1	38.5	17.0	37.0	18.0	32.5	28.0	29.5
86	D	B	1	7.0	11.0	26.0	9.5	17.0	18.5	26.0
87	D	C	1	15.5	28.0	30.0	31.0	8.0	32.5	40.5
88	D	D	1	25.5	6.5	29.5	6.5	32.5	23.0	31.0
89	D	E	1	23.0	52.0	50.0	27.0	29.0	32.0	44.5
90	D	F	1	10.0	24.0	28.0	12.0	29.5	18.5	20.5
91	D	G	1	28.0	29.0	36.0	29.0	5.5	37.0	25.0
92	D	H	1	9.0	16.0	8.0	17.0	5.5	9.0	26.5
93	D	I	1	28.0	8.0	29.0	11.0	53.5	26.0	51.0
94	D	J	1	23.0	11.0	30.5	11.5	28.5	25.5	47.0
95	D	K	1	33.0	23.0	32.0	33.0	44.0	51.0	37.5
96	D	L	1	52.0	47.5	36.0	7.0	11.5	16.0	17.0
97	D	M	1	31.0	12.0	33.0	17.5	37.5	29.0	49.0
98	D	N	1	7.5	14.0	30.5	6.0	28.5	15.0	15.5
99	D	A	2	39.5	19.0	34.0	17.5	39.5	30.0	47.0
100	D	B	2	14.0	15.5	25.0	8.0	24.0	16.5	19.0
101	D	C	2	31.0	25.0	41.0	29.0	8.5	27.0	34.5
102	D	D	2	17.0	10.0	27.0	9.0	33.0	17.0	34.0
103	D	E	2	23.5	52.5	51.0	26.0	39.5	28.5	39.0
104	D	F	2	20.0	23.0	29.5	10.0	31.0	17.0	26.0
105	D	G	2	38.5	26.5	35.0	33.5	5.5	33.0	18.5
106	D	H	2	7.0	7.5	23.5	8.0	4.5	10.0	11.0
107	D	I	2	31.0	13.0	25.0	17.0	52.5	21.5	49.5
108	D	J	2	26.0	15.0	27.0	11.0	24.5	25.0	31.5
109	D	K	2	42.0	27.0	19.5	35.5	34.0	49.0	35.5
110	D	L	2	27.0	36.0	40.5	6.0	14.5	9.0	16.5
111	D	M	2	30.5	12.0	32.0	14.5	40.5	24.5	46.5
112	D	N	2	18.0	19.5	31.0	10.5	27.0	14.5	22.0

Sensory Data con't.

OBS	PANELIST	FABRIC	REP	SURTEX	SURCON	SURFRI	COMPRES	FLEX	THICK	WEIGHT
113	E	A	1	27.5	15.0	21.5	20.5	26.0	27.0	39.5
114	E	B	1	21.5	10.0	27.5	10.0	17.5	16.5	26.5
115	E	C	1	24.0	48.0	50.5	27.0	4.5	28.5	33.0
116	E	D	1	21.0	5.5	25.0	20.0	27.5	22.0	37.5
117	E	E	1	5.0	47.5	40.5	8.5	17.0	26.0	31.0
118	E	F	1	21.5	21.5	32.5	10.0	34.0	15.0	26.0
119	E	G	1	50.0	30.0	43.0	44.0	0.5	28.0	24.0
120	E	H	1	17.5	5.0	10.5	6.5	1.0	12.0	20.5
121	E	I	1	21.0	8.0	30.0	23.0	49.5	22.5	44.0
122	E	J	1	25.0	10.0	20.0	23.0	31.0	26.0	23.5
123	E	K	1	30.0	19.0	27.5	37.0	7.0	46.0	38.5
124	E	L	1	42.0	52.0	59.5	8.5	23.0	11.5	16.5
125	E	M	1	27.5	21.5	24.5	20.0	33.0	30.0	43.5
126	E	N	1	17.0	24.0	30.0	8.5	30.0	13.0	24.5
127	E	A	2	33.0	11.0	25.0	12.0	27.0	28.0	35.0
128	E	B	2	14.0	13.5	13.5	5.0	21.0	11.0	18.0
129	E	C	2	38.0	46.5	43.0	22.0	1.5	29.0	51.5
130	E	D	2	23.0	15.0	21.5	9.5	28.5	16.0	35.5
131	E	E	2	5.0	51.0	53.0	11.0	17.5	26.5	32.0
132	E	F	2	18.5	36.0	35.0	7.0	33.5	16.0	26.5
133	E	G	2	48.0	53.0	36.0	48.0	0.5	26.0	25.0
134	E	H	2	18.0	7.0	10.0	5.0	0.5	7.5	10.5
135	E	I	2	23.0	10.0	24.0	8.0	50.0	27.5	45.0
136	E	J	2	25.0	21.0	24.0	8.0	35.0	18.0	32.5
137	E	K	2	48.0	30.5	23.5	42.0	1.0	51.0	39.0
138	E	L	2	22.5	44.5	48.0	6.0	4.0	14.0	11.0
139	E	M	2	27.5	26.0	28.0	8.0	28.5	28.5	45.0
140	E	N	2	18.0	25.0	30.0	5.0	27.0	6.5	23.5
141	F	A	1	33.0	13.0	36.0	13.0	23.0	21.5	28.0
142	F	B	1	10.0	19.0	22.5	7.0	16.0	18.5	34.0
143	F	C	1	20.0	50.0	27.5	30.0	18.0	27.0	41.0
144	F	D	1	12.5	8.0	19.5	7.5	19.0	22.5	37.0
145	F	E	1	8.0	30.0	49.0	17.0	19.0	23.0	53.0
146	F	F	1	14.0	15.0	31.5	9.0	17.0	14.0	17.5
147	F	G	1	43.0	42.0	28.0	26.0	20.0	29.0	12.0
148	F	H	1	7.0	7.0	6.5	6.5	17.0	13.0	37.5
149	F	I	1	24.0	7.0	32.0	10.0	30.5	25.0	28.5
150	F	J	1	36.0	1.5	23.0	10.0	27.0	21.0	29.5
151	F	K	1	24.0	33.0	12.5	41.0	26.0	43.0	41.5
152	F	L	1	18.5	51.0	42.5	7.5	8.0	12.5	12.0
153	F	M	1	26.0	14.0	31.5	10.0	24.0	28.5	24.0
154	F	N	1	12.5	20.0	25.0	7.5	27.0	12.0	17.0
155	F	A	2	35.0	15.5	41.5	13.0	41.0	24.5	43.0
156	F	B	2	12.0	13.0	33.0	7.0	26.5	20.5	29.0
157	F	C	2	27.0	52.5	30.0	28.0	7.5	26.0	29.0
158	F	D	2	20.0	21.0	21.0	9.0	32.0	21.5	34.0
159	F	E	2	3.5	43.5	37.5	9.0	34.5	26.5	47.0
160	F	F	2	27.0	33.5	25.0	7.0	36.5	14.0	49.0
161	F	G	2	32.0	37.5	24.5	30.0	7.5	28.0	24.5
162	F	H	2	5.0	7.5	28.0	22.0	3.0	10.0	19.0
163	F	I	2	38.0	9.0	36.0	18.5	48.0	28.0	35.0
164	F	J	2	25.0	10.0	35.5	12.5	36.0	21.0	25.0
165	F	K	2	24.0	30.0	16.0	26.0	24.5	43.5	36.5
166	F	L	2	15.0	41.5	44.5	10.5	17.5	14.0	22.0
167	F	M	2	29.5	18.0	35.5	24.0	33.5	28.5	30.0
168	F	N	2	27.0	22.0	24.0	16.0	36.5	16.5	32.0

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OBS	PANELIST	FABRIC	REP	SURTEX	SURCON	SURFRI	COMPRES	FLEX	THICK	WEIGHT
169	G	A	1	34.5	7.0	36.5	23.0	27.5	27.0	36.0
170	G	B	1	7.0	7.0	13.0	7.0	22.0	12.5	17.5
171	G	C	1	34.0	43.0	49.0	29.0	8.0	25.0	31.5
172	G	D	1	19.0	10.0	32.0	8.0	27.0	15.5	42.5
173	G	E	1	6.0	49.0	33.0	26.0	11.0	23.0	32.0
174	G	F	1	22.0	29.0	33.0	5.5	28.0	16.0	24.0
175	G	G	1	33.0	30.0	46.0	36.5	4.0	28.5	30.0
176	G	H	1	8.0	5.0	12.0	5.0	4.0	5.0	15.0
177	G	I	1	27.0	8.0	34.0	8.0	43.5	30.0	44.5
178	G	J	1	43.0	8.0	42.0	8.0	28.5	17.0	27.5
179	G	K	1	30.0	13.0	38.0	24.0	16.5	43.5	48.5
180	G	L	1	18.0	32.0	45.0	8.0	15.5	7.0	12.0
181	G	M	1	30.0	13.0	45.0	17.5	32.0	27.0	49.0
182	G	N	1	19.5	20.0	30.0	5.0	30.0	9.0	25.0
183	G	A	2	34.5	14.0	37.0	31.0	36.0	28.5	34.5
184	G	B	2	8.5	8.0	21.0	7.0	16.0	13.0	36.5
185	G	C	2	28.0	42.0	42.5	30.0	3.0	28.5	50.0
186	G	D	2	24.0	9.0	26.0	11.0	33.5	30.0	47.5
187	G	E	2	7.0	35.0	42.5	22.5	27.5	28.0	30.0
188	G	F	2	30.0	32.5	33.5	5.0	34.5	8.5	25.5
189	G	G	2	24.5	46.5	49.5	35.0	2.0	30.0	30.0
190	G	H	2	6.0	5.5	10.0	5.0	2.0	5.0	11.0
191	G	I	2	30.0	10.0	30.5	8.0	44.5	30.0	52.5
192	G	J	2	30.0	10.5	32.0	10.5	30.0	26.5	29.0
193	G	K	2	24.5	12.0	38.5	38.0	27.0	45.5	51.0
194	G	L	2	24.0	35.0	47.0	8.0	17.0	10.0	23.5
195	G	M	2	34.5	19.0	47.5	11.0	36.5	30.0	42.0
196	G	N	2	10.5	10.0	32.0	8.0	30.0	14.5	22.5
197	H	A	1	26.0	27.0	22.0	18.5	31.0	26.0	34.0
198	H	B	1	15.0	20.0	28.0	8.0	18.0	14.0	23.5
199	H	C	1	50.5	55.0	49.0	32.0	23.0	33.0	37.0
200	H	D	1	26.0	9.0	25.0	11.5	30.0	18.5	33.0
201	H	E	1	7.5	50.0	55.0	26.5	31.5	24.0	25.5
202	H	F	1	25.0	32.0	36.5	12.0	31.5	11.0	27.0
203	H	G	1	30.0	50.0	30.0	30.0	7.5	28.0	27.0
204	H	H	1	9.5	10.0	10.0	9.5	2.5	7.5	17.0
205	H	I	1	28.0	18.0	34.0	11.5	55.0	26.0	25.0
206	H	J	1	30.0	14.0	22.0	11.5	28.5	18.5	30.0
207	H	K	1	25.0	37.0	29.0	38.5	33.0	43.0	33.0
208	H	L	1	25.0	50.0	35.0	7.0	28.0	14.0	18.0
209	H	M	1	28.0	25.0	24.0	26.5	42.0	24.0	46.0
210	H	N	1	22.0	28.0	36.5	7.5	30.0	11.0	15.0
211	H	A	2	38.0	23.5	30.0	14.5	30.0	27.5	33.0
212	H	B	2	11.0	10.0	22.0	6.5	14.5	10.0	26.0
213	H	C	2	50.0	52.0	40.0	30.0	9.0	26.5	23.0
214	H	D	2	29.0	14.0	28.5	7.5	32.0	21.0	49.5
215	H	E	2	5.0	54.0	53.0	10.0	25.0	31.0	28.5
216	H	F	2	18.0	31.0	30.0	6.5	23.0	11.5	22.0
217	H	G	2	24.0	34.0	26.5	28.0	5.0	27.5	16.0
218	H	H	2	5.0	15.0	18.5	12.0	5.0	10.0	16.0
219	H	I	2	30.0	19.5	27.5	12.0	53.0	28.0	22.0
220	H	J	2	38.0	20.5	24.0	7.5	14.5	17.5	26.0
221	H	K	2	17.0	34.0	32.0	42.0	28.0	43.0	30.0
222	H	L	2	11.5	47.0	33.5	7.5	15.0	10.5	14.0
223	H	M	2	30.0	18.0	26.5	13.5	40.5	30.0	37.5
224	H	N	2	24.0	28.0	30.0	6.0	23.0	10.0	24.0

Appendix 5

Univariate Statistics for the Properties

Table 30. Univariate Statistics for Surface Texture.

Fabric Sample	Mean[1]	Standard Deviation	Standard Error of the Mean
A	34.97	5.62	1.40
B	12.59	4.88	1.22
C	31.63	11.21	2.80
D	22.56	5.09	1.27
E	12.13	12.02	3.00
F	17.78	6.26	1.57
G	34.28	8.20	2.05
H	10.19	5.29	1.32
I	28.03	4.06	1.01
J	29.13	5.75	1.44
K	31.38	8.36	2.09
L	21.97	11.93	2.98
M	30.09	6.56	1.64
N	15.91	6.29	1.57

Note: [1] N = 16, from 2 replications by 8 panelists.

Table 31. Univariate Statistics for Surface Contour.

Fabric Sample	Mean	Standard Deviation	Standard Error of the Mean
A	16.19	5.51	1.38
B	13.03	4.95	1.24
C	45.31	10.12	2.53
D	13.00	5.98	1.50
E	42.63	9.35	2.34
F	25.41	6.78	1.69
G	38.50	8.79	2.20
H	7.88	3.20	0.80
I	11.38	3.95	0.99
J	12.38	5.74	1.44
K	26.38	7.88	1.97
L	42.25	7.84	1.96
M	18.78	5.82	1.45
N	19.34	5.42	1.36

Table 32. Univariate Statistics for Surface Friction.

Fabric Sample	Mean	Standard Deviation	Standard Error of the Mean
A	33.47	6.92	1.73
B	22.78	6.72	1.68
C	41.34	7.67	1.92
D	26.03	6.04	1.51
E	44.91	7.79	1.95
F	30.53	4.31	1.08
G	37.38	7.39	1.85
H	12.81	6.75	1.69
I	28.13	6.26	1.57
J	27.59	6.74	1.68
K	31.25	10.20	2.55
L	43.66	6.45	1.61
M	32.72	7.20	1.80
N	29.38	3.32	0.83

Table 33. Univariate Statistics for Compressibility.

Fabric Sample	Mean	Standard Deviation	Standard Error of the Mean
A	18.78	5.77	1.44
B	7.81	1.39	0.35
C	29.22	2.63	0.66
D	11.69	4.28	1.07
E	19.22	6.88	1.72
F	8.97	2.72	0.68
G	31.47	6.82	1.71
H	9.47	4.67	1.17
I	13.19	5.13	1.28
J	11.63	3.69	0.92
K	35.25	5.40	1.35
L	8.09	1.83	0.46
M	17.28	5.88	1.47
N	8.16	2.59	0.65

Table 34. Univariate Statistics for Flexibility.

Fabric Sample	Mean	Standard Deviation	Standard Error of the Mean
A	31.63	5.52	1.38
B	21.34	4.74	1.19
C	9.34	5.65	1.41
D	30.25	3.89	0.97
E	24.78	7.77	1.94
F	30.38	5.64	1.41
G	6.50	5.25	1.31
H	4.44	3.82	0.96
I	48.34	6.87	1.72
J	27.06	6.40	1.60
K	25.44	10.30	2.57
L	17.75	7.98	1.99
M	36.41	6.84	1.71
N	28.72	4.22	1.05

Table 35. Univariate Statistics for Thickness.

Fabric Sample	Mean	Standard Deviation	Standard Error of the Mean
A	26.22	2.36	0.59
B	14.22	3.02	0.76
C	27.34	2.94	0.73
D	19.53	4.35	1.09
E	24.06	4.66	1.17
F	13.59	2.63	0.66
G	28.00	3.72	0.93
H	8.66	2.47	0.62
I	25.59	2.98	0.75
J	20.88	3.64	0.91
K	44.84	3.91	0.98
L	11.47	2.43	0.61
M	27.16	2.85	0.71
N	11.31	2.88	0.72

Table 36. Univariate Statistics for Weight.

Fabric Sample	Mean	Standard Deviation	Standard Error of the Mean
A	36.16	5.78	1.45
B	25.22	5.56	1.39
C	35.63	7.57	1.89
D	38.50	5.85	1.46
E	33.38	8.18	2.05
F	24.56	8.15	2.04
G	22.69	6.91	1.73
H	15.72	7.47	1.87
I	37.44	9.69	2.42
J	28.06	6.67	1.67
K	42.94	7.63	1.91
L	14.75	4.61	1.15
M	42.06	8.75	2.19
N	21.91	5.96	1.49

Appendix 6

The Differences Between Replications One and Two for the Properties

Table 37. Differences Between Replications One and Two for Surface Texture

Fabric Sample	Panelists A	B	C	D	E	F	G	H
A	-14.00	-4.00	6.00	-1.00	-5.50	-2.00	0.00	-12.00
B	0.00	-13.00	-2.50	-7.00	7.50	-2.00	-1.50	4.00
C	0.00	-17.00	6.00	-15.50	-14.00	-7.00	6.00	0.50
D	-8.00	-12.00	10.00	8.50	-2.00	-7.50	-5.00	-3.00
E	1.00	-43.50	1.00	-0.50	0.00	4.50	-1.00	2.50
F	-3.50	-6.00	-2.00	-10.00	3.00	-13.00	-8.00	7.00
G	12.00	4.50	2.00	-10.50	2.00	11.00	8.50	6.00
H	-1.00	-5.00	-1.00	2.00	-0.50	2.00	2.00	4.50
I	-7.00	-2.50	-1.00	-3.00	-2.00	-14.00	-3.00	-2.00
J	-9.50	-1.00	-1.50	-3.00	0.00	11.00	13.00	-8.00
K	-3.00	-0.50	3.00	-9.00	-18.00	0.00	5.50	8.00
L	3.00	11.50	3.50	25.00	19.50	3.50	-6.00	13.50
M	-13.00	-20.00	16.00	0.50	0.00	-3.50	-4.50	-2.00
N	-1.50	-16.50	-3.50	-10.50	-1.00	-14.50	9.00	-2.00

Table 38. Differences Between Replications One and Two for Surface Contour.

Fabric Sample	Panelists A	B	C	D	E	F	G	H
A	8.50	-10.00	2.50	-2.00	4.00	-2.50	-7.00	3.50
B	0.00	9.00	-0.50	-4.50	-3.50	6.00	-1.00	10.00
C	0.00	23.00	15.00	3.00	1.50	-2.50	1.00	3.00
D	8.00	-2.00	-2.00	-3.50	-9.50	-13.00	1.00	-5.00
E	23.00	8.00	1.50	-0.50	-3.50	-13.50	14.00	-4.00
F	-11.50	-6.00	10.50	1.00	-14.50	-18.50	-3.50	1.00
G	-2.00	-8.00	-0.50	2.50	-23.00	4.50	-16.50	16.00
H	1.00	0.00	0.50	8.50	-2.00	-0.50	-0.50	-5.00
I	2.00	-10.00	-0.50	-5.00	-2.00	-2.00	-2.00	-1.50
J	1.50	-14.00	4.00	-4.00	-11.00	-8.50	-2.50	-6.50
K	10.00	-5.50	-11.00	-4.00	-11.50	3.00	1.00	3.00
L	6.00	-1.50	12.00	11.50	7.50	9.50	-3.00	3.00
M	-1.00	1.00	-2.00	0.00	-4.50	-4.00	-6.00	7.00
N	2.00	-10.00	5.00	-5.50	-1.00	-2.00	10.00	0.00

Table 39. Differences Between Replications One and Two for Surface Friction.

Fabric Sample	Panelists A	B	C	D	E	F	G	H
A	2.50	-1.00	-4.50	3.00	-3.50	-5.50	-0.50	-8.00
B	0.00	-22.00	-3.00	1.00	14.00	-10.50	-8.50	6.00
C	0.00	0.00	3.00	-11.00	7.50	-2.50	6.50	9.00
D	-3.50	-12.50	-19.50	2.50	3.50	-1.50	6.00	-3.50
E	-7.00	5.00	-4.00	-1.00	-12.50	11.50	-9.50	2.00
F	-0.50	3.50	-3.00	-1.50	-2.50	6.50	-0.50	6.50
G	-5.00	-1.50	7.00	1.00	7.00	3.50	-3.50	3.50
H	-2.00	-1.00	-14.00	-15.50	0.50	-21.50	2.00	-8.50
I	-2.00	-1.50	-14.50	4.00	6.00	-4.00	3.50	6.50
J	9.00	-4.50	0.00	3.50	-4.00	-12.50	10.00	-2.00
K	-10.50	9.00	-2.00	12.50	4.00	-3.50	-0.50	-3.00
L	-2.00	-1.00	-7.00	-4.50	11.50	-2.00	-2.00	-2.50
M	18.50	-6.00	2.50	1.00	-3.50	-4.00	-2.50	-2.50
N	-1.50	-8.00	3.50	-0.50	0.00	1.00	-2.00	6.50

Table 40. Differences Between Replications One and Two for Compressibility.

Fabric Sample	Panelists A	B	C	D	E	F	G	H
A	-3.50	8.50	-2.50	0.50	8.50	0.00	-8.00	4.00
B	0.00	2.50	-1.50	1.50	5.00	0.00	0.00	1.50
C	0.00	-1.00	0.50	2.00	5.00	2.00	-1.00	2.00
D	4.00	7.00	-4.50	-2.50	10.50	-1.50	-3.00	4.00
E	5.00	6.00	-11.00	1.00	-2.50	8.00	3.50	16.50
F	1.00	9.00	1.50	2.00	3.00	2.00	0.50	5.50
G	7.00	-0.50	0.00	-4.50	-4.00	-4.00	1.50	2.00
H	1.50	-2.00	-4.50	9.00	1.50	-15.50	0.00	-2.50
I	-2.00	2.00	-12.00	-6.00	15.00	-8.50	0.00	-0.50
J	-1.50	-6.00	0.00	0.50	15.00	-2.50	-2.50	4.00
K	1.50	-4.00	3.50	-2.50	-5.00	15.00	-14.00	-3.50
L	6.00	-2.50	2.00	1.00	2.50	-3.00	0.00	-0.50
M	1.00	10.00	-10.00	3.00	12.00	-14.00	6.50	13.00
N	-1.00	-2.00	0.50	-4.50	3.50	-8.50	-3.00	1.50

Table 41. Differences Between Replications One and Two for Flexibility.

Fabric Sample	Panelists A	B	C	D	E	F	G	H
A	-11.00	4.00	5.50	-7.00	-1.00	-18.00	-8.50	1.00
B	-10.00	-4.50	1.50	-7.00	-3.50	-10.50	6.00	3.50
C	-0.50	12.00	0.00	-0.50	3.00	10.50	5.00	14.00
D	-7.50	-3.00	-1.50	-0.50	-1.00	-13.00	-6.50	-2.00
E	1.00	4.00	0.00	-10.50	-0.50	-15.50	-16.50	6.50
F	8.00	3.00	0.50	-1.50	0.50	-19.50	-6.50	8.50
G	-3.00	0.00	-8.00	0.00	0.00	12.50	2.00	2.50
H	-3.00	2.00	0.00	1.00	0.50	14.00	2.00	-2.50
I	7.00	-2.00	-2.50	1.00	-0.50	-17.50	-1.00	2.00
J	-6.00	10.50	-16.00	4.00	-4.00	-9.00	-1.50	14.00
K	3.00	3.50	-3.50	10.00	6.00	1.50	-10.50	5.00
L	-6.00	11.00	12.00	-3.00	19.00	-9.50	-1.50	13.00
M	-15.50	12.00	5.00	-3.00	4.50	-9.50	-4.50	1.50
N	-7.00	-3.50	-4.00	1.50	3.00	-9.50	0.00	7.00

Table 42. Differences Between Replications One and Two for Thickness.

Fabric Sample	Panelists A	B	C	D	E	F	G	H
A	1.00	6.00	-0.50	-2.00	-1.00	-3.00	-1.50	-1.50
B	0.00	1.50	1.00	2.00	5.50	-2.00	-0.50	4.00
C	0.00	-5.00	0.50	5.50	-0.50	1.00	-3.50	6.50
D	0.00	-5.50	5.00	6.00	6.00	1.00	-14.50	-2.50
E	3.00	-1.50	1.00	3.50	-0.50	-3.50	-5.00	-7.00
F	-0.50	-3.50	-1.00	1.50	-1.00	0.00	7.50	-0.50
G	2.50	6.00	3.50	4.00	2.00	1.00	-1.50	0.50
H	-1.50	-1.50	4.50	-1.00	4.50	3.00	0.00	-2.50
I	-1.00	-6.50	5.50	4.50	-5.50	-3.00	0.00	-2.00
J	-4.00	-1.00	1.00	0.50	8.00	0.00	-9.50	1.00
K	0.50	-6.50	3.00	2.00	-5.00	-0.50	-2.00	0.00
L	-2.00	0.50	0.50	7.00	-2.50	-1.50	-3.00	3.50
M	-4.00	0.50	-4.00	4.50	1.50	0.00	-3.00	-6.00
N	4.00	1.00	-2.00	0.50	6.50	-4.50	-5.50	1.00

Table 43. Differences Between Replications One and Two for Weight.

Fabric	Panelists							
Sample	A	B	C	D	E	F	G	H
A	-5.00	10.00	12.00	-17.50	4.50	-15.00	1.50	1.00
B	0.00	6.00	-5.50	7.00	8.50	5.00	-19.00	-2.50
C	0.00	-1.00	8.00	6.00	-18.50	12.00	-18.50	14.00
D	7.00	-10.00	4.50	-3.00	2.00	3.00	-5.00	-16.50
E	0.00	-6.50	1.00	5.50	-1.00	6.00	2.00	-3.00
F	16.00	-12.50	4.50	-5.50	-0.50	-31.50	-1.50	5.00
G	-17.00	5.00	5.00	6.50	-1.00	-12.50	0.00	11.00
H	5.50	1.50	2.50	15.50	10.00	18.50	4.00	1.00
I	-1.50	8.50	-3.00	1.50	-1.00	-6.50	-8.00	3.00
J	10.00	8.00	7.50	15.50	-9.00	4.50	-1.50	4.00
K	10.00	-2.50	2.50	2.00	-0.50	5.00	-2.50	3.00
L	-2.00	-12.50	2.00	0.50	5.50	-10.00	-11.50	4.00
M	24.50	8.50	4.50	2.50	-1.50	-6.00	7.00	8.50
N	12.50	-15.50	5.00	-6.50	1.00	-15.00	2.50	-9.00

Appendix 7

Instrument Measurement Results for the Properties

Table 44. Instrumental Measurement Values.

Fabric Sample	Coefficient of Static Friction (g)	Compression (mm)	Flexural Rigidity (mg/m^2)	Thickness (mm)	Weight (g/m^2)
A	1.67	0.42	458.7	1.39	255
B	1.78	0.19	276.5	0.78	195
C	1.65	0.85	192.8	1.71	230
D	1.99	0.29	463.9	0.91	261
E	1.59	0.37	254.0	1.37	239
F	1.57	0.29	352.6	0.64	213
G	1.41	0.89	232.7	1.99	244
H	1.59	0.19	42.6	0.51	140
I	1.72	0.33	812.4	1.30	267
J	1.70	0.38	251.8	1.07	210
K	1.22	1.33	1070.6	3.43	389
L	1.14	0.28	252.8	0.68	122
M	1.95	0.39	618.9	1.51	308
N	1.64	0.20	550.2	0.54	169