THE EFFECT OF CHAIR STYLE AND COVERING ON THERMAL COMFORT

by

KRISTI ANDERSON-SUNDLIE

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Chapter 1

INTRODUCTION

In the United States energy conservation awareness has become a prevalent attitude as a result of the shortages and high prices of petroleum during the 1970's. Although federal emergency energy measures have been revoked as of March 8, 1982 (96), there has been continued emphasis on the importance of energy conservation. This has added a new dimension to America's concern about the future and about maximizing available resources.

The business world is especially concerned about maximizing their resources which include energy, money, and people's productivity. Business continually attempts to get the most out of the available energy and finances without sacrificing productivity. Although it has been documented that regulating thermostats reduces energy consumption significantly (52), it is uncertain how these temperature changes affect productivity (37,38,62,75,93).

An important aspect of these concerns by business is employee comfort in and satisfaction with their working environment. In 1979 a survey on Comfort and Productivity in the Office of the 80's was conducted by Louis Harris and Associates for Steelcase (50). It was found that 73% of those surveyed considered a comfortable chair to be very important to job comfort. In addition, 69% felt that "the right temperature" is also very *important.* Those who felt most strongly about having 'the right temperature' were those aged 40 and over, secretaries, and women (50).

Rohles and Krohn (77) related these survey results to a research study on the effect of chair model and covering on thermal comfort. They tested 192 subjects in four chair models, each model covered with a cloth and a vinyl upholstery fabric, for two hours at 25.6°C (78°F) at 50% relative humidity. They found that although thermal sensation was not affected by chair model or covering, thermal comfort was significantly affected by the chair covering. The subjects showed higher thermal comfort in chairs covered with cloth than in those covered with vinyl. Cloth upholstered chairs were also found to be preferred in a study by the National Conference Center, but not specifically because of thermal factors (77). Rohles and Krohn found no difference in the general comfort of the chairs studied.

Research on the relationship between people and their environment has been evolving since the 1920's. Much of this early work was accomplished by heating and ventilating engineers, responsible for the task of providing a livable indoor environment (18). Houghten and Yaglou were early environmental pioneers who set out to develop an effective temperature index to stand as a reference to describe combinations of temperature, humidity, and air velocity that felt equally warm (33,34). Later, environmental physiologists began to quantify measures of the heat exchange process in humans (18). Man's responses to extreme environments were of interest during the war years and during the space exploration advances (18). In the 1960's the heating and ventilating engineers again concentrated on thermal comfort in the immediate every day environment (18). Engineers, psychologists, and physiologists have made extensive studies of many of the factors that influence the relationship between people and their physical environment.

The Rohles and Krohn study was conducted in a test room kept at 25.6°C (78°F). However, with the present concern for energy conservation, this temperature is higher than those found in most offices during the winter months, especially in the Northern climates, with the now common regulation of thermostats. Rohles speculated on the possible differences in the effects of these chair coverings at both lower and higher temperatures and suggested the need for further research (77).

The proposed study will investigate the effect of chair model and chair covering on sedentary subject's responses to the thermal environment and to various chair attributes under controlled environmental conditions simulating cool, neutral, and warm office environments. Women only will be chosen as subjects for the following reasons: 1) the Steelcase/Harris survey found that a comfortable chair and "the right temperature" were more important to the women surveyed than to the men, 2) with the increased number of women in the workplace, their comfort becomes increasingly important, 3) those who will be designing and purchasing office furniture, a majority of whom are men (50), should be aware of the effect of chair covering on the comfort of those who will be using the chairs, and 4) this research study becomes more economically feasible by examining women's responses alone. Additional research could be conducted to find out if the thermal responses of men, while seated in these chairs and coverings, would vary significantly from the responses of women.

Objectives

1. To determine whether the thermal responses of female students are affected by different environmental temperatures, different chair models, different chair coverings, and/or the passage of time.
2. To determine whether the responses of female students to the subjective Chair Attribute Scale are affected by environmental temperature, chair model, chair upholstery, and/or the passage of time.

Definitions

Thermal Comfort: A general term describing the condition of mind which expresses satisfaction with the environment (37).

Effective Temperature (ET*): "the uniform temperature of a radiantly black enclosure at 50% relative humidity, in which an occupant would experience the same comfort, physiological strain and heat exchange as in the actual environment with the same air motion" (2;p.1).

Thermal Sensation: "a conscious experience resulting from exposure to a class of variables making up the thermal environment" (67; p.98).

Thermal Sensation Scale: a subjective scale which lists thermal sensations as illustrated below: (77; p.2)

Very Hot	9
Hot	8
Warm	7
Slightly Warm	6
Neutral	5
Slightly Cool	4
Cool	3
Cold	2
Very Cold	1

Thermal Comfort Rating: a summed value of ratings ranging from one to nine representing the least to most desirable adjective, respectively, of each of seven pairs of adjectives in a semantic differential scale as illustrated below: (77; p.2)

According to the instructions, place a check between each pair of adjectives at the location that best describes how you feel:

comfortable	_,_,_,_,_,_,_,_,_	uncomfortable
bad temperature	_,_,_,_,_,_,_,_,_	good temperature
pleasant	_,_,_,_,_,_,_,_,_	unpleasant
cool	_,_,_,_,_,_,_,_,_	warm
unacceptable	_,_,_,_,_,_,_,_,_	acceptable
uncomfortable temperature	_,_,_,_,_,_,_,_,_	comfortable temperature
satisfied	_,_,_,_,_,_,_,_,_	dissatisfied

Temperature Preference Scale: a temperature scale which the subject uses to describe the increase or decrease in temperature necessary to obtain the preferred environment, as illustrated below:

___ +10
___ + 9
___ + 8
___ + 7
___ + 6
___ + 5
___ + 4
___ + 3
___ + 2
___ + 1
___ 0 ^{o}F
___ - 1
___ - 2
___ - 3
___ - 4
___ - 5
___ - 6
___ - 7
___ - 8
___ - 9
___ -10
___

Chair Attribute Scale: "a 20 (sic) adjective-pair semantic differential scale designed to measure the non-thermal characteristics of the chair itself" (77; p.2):

According to the instructions, place a check between each pair of adjectives at the location that best describes the chair:

Style:	Unfashionable	_,_,_,_,_,_,_	fashionable
	ugly	_,_,_,_,_,_,_	beautiful
	attractive	_,_,_,_,_,_,_	unattractive
	unstylish	_,_,_,_,_,_,_	stylish
	repelling	_,_,_,_,_,_,_	inviting
	bad lines	_,_,_,_,_,_,_	good lines
	unappealing	_,_,_,_,_,_,_	appealing
Size:	large	_,_,_,_,_,_,_	small
	cramped	_,_,_,_,_,_,_	roomy
	huge	_,_,_,_,_,_,_	tiny
	narrow	_,_,_,_,_,_,_	wide
Comfort:	functional	_,_,_,_,_,_,_	non-functional
	uncomfortable	_,_,_,_,_,_,_	comfortable
	unpleasant	_,_,_,_,_,_,_	pleasant
	poorly balanced	_,_,_,_,_,_,_	well balanced
	inconvenient	_,_,_,_,_,_,_	convenient
	inefficient	_,_,_,_,_,_,_	efficient

Limitations

This study was limited to female students at Kansas State University, Spring Semester, 1983. The students were paid volunteers which may have influenced their attitudes towards the study.

The study was conducted in the KSU-ASHRAE controlled laboratory environment which simulated various office conditions. However, in a functioning office the many variables are not controlled to the same extent. Many factors contribute to feelings of comfort and are very difficult to isolate in field studies. Office workers are likely to experience drafts or assymetric temperatures in the less highly controlled building which would affect thermal response differently, to some extent, than those students tested in the controlled chamber.

Assumptions

Female students at Kansas State University are representative of the population of Mid-Western females ages 18 - 24.

The clothing ensembles worn are representative of that typically worn by office workers throughout the United States.

The temperatures tested (20.0°CET* (68°FET*), 22.8°CET* (73°FET*), and 26.1°CET* (79°FET*)) are representative of cool winter, neutral, and minimally air-conditioned summer office environments.

Chapter 2

REVIEW OF THE LITERATURE

The investigation of human response to the surrounding physical environment has been the subject of research for over 50 years. Houghten and Yaglou began their search for a comfort zone in the 1920's (33,34,35,94,95). Despite their great contribution to the study of thermal comfort, the results of much early work cannot be directly applied today because many of the variables were not controlled. Since Houghten and Yaglou's beginnings, other researchers have joined with them to define and refine the various aspects of thermal comfort study (11,23,57,64,72,86).

The goal of thermal comfort research is to predict the comfort of people quantitatively (42). This is not the simple task it may seem at the outset. Temperature, humidity, and air velocity are only three of a myriad of variables which influence thermal response in a given environment. Rohles has divided these variables into three categories which, in interaction, form the ecosystem complex (64,73). He describes the physical, organismic, and reciprocative variables that must be controlled or specified in any type of environmental research (64). Physical variables are those which are most often considered in environmental study and include sound, light, area-volume, radiation, inspired gas, atmospheric

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unwanted variables are vary difficult to control. The most commonly used method for environmental research involves controlling as many variables as possible by testing subjects in environmentally controlled chambers. Test chambers have been built in which air temperature, radiant temperature, humidity, and air flow can be carefully regulated (39). The subjects commonly record their reactions on thermal sensation and thermal comfort scales while changes in various physiological measures, most often skin temperature, are monitored (65). In this way many subjects can be studied and generalizations can be made. Contradictory results are sometimes found when these methods are compared because people responding to a survey may behave differently than people in an artificially controlled chamber, but all types of studies are important for a complete understanding of thermal response. Field studies have been utilized to validate theoretically derived formulas (16,36,37). In combining methods, Howell and Kennedy compared predictions using Fanger's comfort equation with responses of people in a variety of work and school environments and found the equation to be a good first approximation, but that other psychological variables are also involved (36). People were found to be adaptable to a wide range of physical conditions with behavioral, cognitive, and physiological adjustments.

In controlled laboratory experiments many factors have been tested to assess their effects on thermal response. The main variables which affect dry heat exchange are dry bulb temperature, mean radiant temperature, relative humidity, air movement, activity, and clothing insulation (2). The length of time spent in a given environment also influences thermal response (42,76).

Thermal response of the nude human body depends on the equalization of heat production, or metabolic rate, and heat dissipation through radiation, convection, and evaporation in order to maintain a relatively constant deep body temperature (15,26,35). Gagge has enumerated the variables that regulate this heat exchange (18). Physiological variables include 1) metabolic energy, 2) average skin temperature, 3) rectal or esophageal temperature, 4) rate of regulatory sweating, and 5) mechanical efficiency for doing work. Environmental variables include 1) air temperature, 2) barometric pressure, 3) radiant temperature, 4) vapor pressure, 5) air movement, 6) clothing insulation, and 7) time of exposure. Skin temperature has been found to be closely related to thermal comfort, especially in the cold, and has been used to evaluate subjects' response in research (18,19,24,31). Skin temperature is influenced by the rate of heat production in the body, the amount of clothing insulation, and the environmental temperature (42). The rate of heat production in the body is a fuction of activity, which is relatively constant in a given office environment. Clothing insulation is one variable people can increase or decrease easily to change their comfort. The environmental temperature is often regulated and not controlled by the average person in an office environment, but much research has been done to find the temperature/humidity zones in which the majority of people are comfortable (2,34,57,76).

Houghten and Yaglou developed the first Effective Temperature (ET), "an index of the degree of warmth which a person will experience for all combinations of temperature and humidity" (34; p.364). They went on to add an air velocity variable to the index (33). At that time, 1924, they found the "true comfort line" to be 18.1°CET (64.5°FET). The comfort zones established were 17.2° - 21.7°CET (63° - 71°FET) for winter and 18.9° - 23.9°CET (66° - 75°FET) for summer (5). The ET developed by Houghten and Yaglou was modified by the addition of radiant heat as a variable by Bedford in 1948 (29). Gagge, et al, later modified this index to relate to a more universally applicable environment at 50% relative humidity instead of the unrealistic saturated atmosphere of the previous scales (23). Their New Effective Temperature (ET*) is that used today to predict thermal sensation through regression equations developed by Rohles (75).

These ET and ET* indices have been used to produce comfort charts, a practical method to easily see the temperature, humidity, air movement, and radiant temperature combinations that produce the comfort line (2,57,58). These lines have been evaluated and re-evaluated throughout the past 50 years to reflect the changes in population preference of the ET (40,42,57,76). Nevins found the comfort line to be at 25.6°CET (78°FET), 7.5°C (13.5°F) higher than Houghten and Yaglou had described (57). This change has been attributed to a change in clothing habits and higher comfort expectations in indoor environments.

The early comfort charts illustrated a specific line describing the various conditions that would result in thermal comfort of the majority of people. However, Rohles stated that,

> . . . from a purely operational point of view, this is totally impractical since there is nothing in the way of a range or plus and minus limits about that line. Moreover, the requirements for limits of this type becomes more apparent when we consider that the data used in the construction of the line itself are based on value judgements of unknown reliability and not on any objective measure (73; p.88).

Especially in nonstressful temperatures there is increased inter- and intra- subject variability so a single temperature cannot be practically predicted for universal thermal comfort (67). Thus, the now common comfort zones, or modal comfort envelopes, have been developed (57,68,70). Rohles and Nevins have conducted extensive research using hundreds of subjects in a wide range of temperatures and humidities to develop a set of 15 thermal conditions in order to define the comfort zone and to provide a set of valid conditions to be used for future research on other variables involved in comfort, such as age, clothing, activity, color of the room, and illumination level (68,70).

P.O. Fanger has developed a comfort equation which predicts thermal comfort of the highest possible percentage of college-aged Americans under steady state conditions for longer than two hours (14). Various combinations of the following variables were calculated by Fanger: air temperature, humidity, mean radiant temperature, relative humidity, mean radiant temperature, relative air velocity, activity level, and insulation value of clothing. The equation was then used, with the aid of a computer, to develop charts to give comfort zones for practical use by environmental engineers.

ASHRAE (The American Society of Heating, Refrigerating and Air-conditioning Engineers) has published a standard comfort zone, describing environmental conditions in which "the body is able to maintain a balance between heat production and heat loss without significant changes in any of the readily measurable indices of thermal comfort" (47). The present comfort zone for winter ranges from 20.0 - 23.6^{o}CET* (68^{o} - 74.5^{o}FET*) and for summer 22.8^{o} - 26.1^{o}CET* (73^{o} - 79^{o}FET*) (2), considerably higher than Houghten and Yaglou's original zones. This chart is used by engineers to develop comfort conditions for use in situations where people are involved in "light, mainly sedentary activity (≤1.2 met)" (2; p.5). (See Figure 1).

The rate of activity regulates internal heat production, and so, thermal response (4). Gagge, Burton, and Bazett proposed the activity unit, 1 met, to equal "the metabolism of a subject resting in a sitting position under conditions of thermal comfort", a condition which results in 50 calories burned per hour per square meter of surface area of the individual (18.5 BTU per hour per square foot) (17; p.429). An average male sitting and using moderate arm and leg movements, as in typing, would have a metabolic rate of 600 Btuh. This would increase to 800 Btuh if arm and leg movements were heavy, as in walking three miles an hour. A metabolic rate of 1000 Btuh results from walking with moderate lifting or pushing (47).

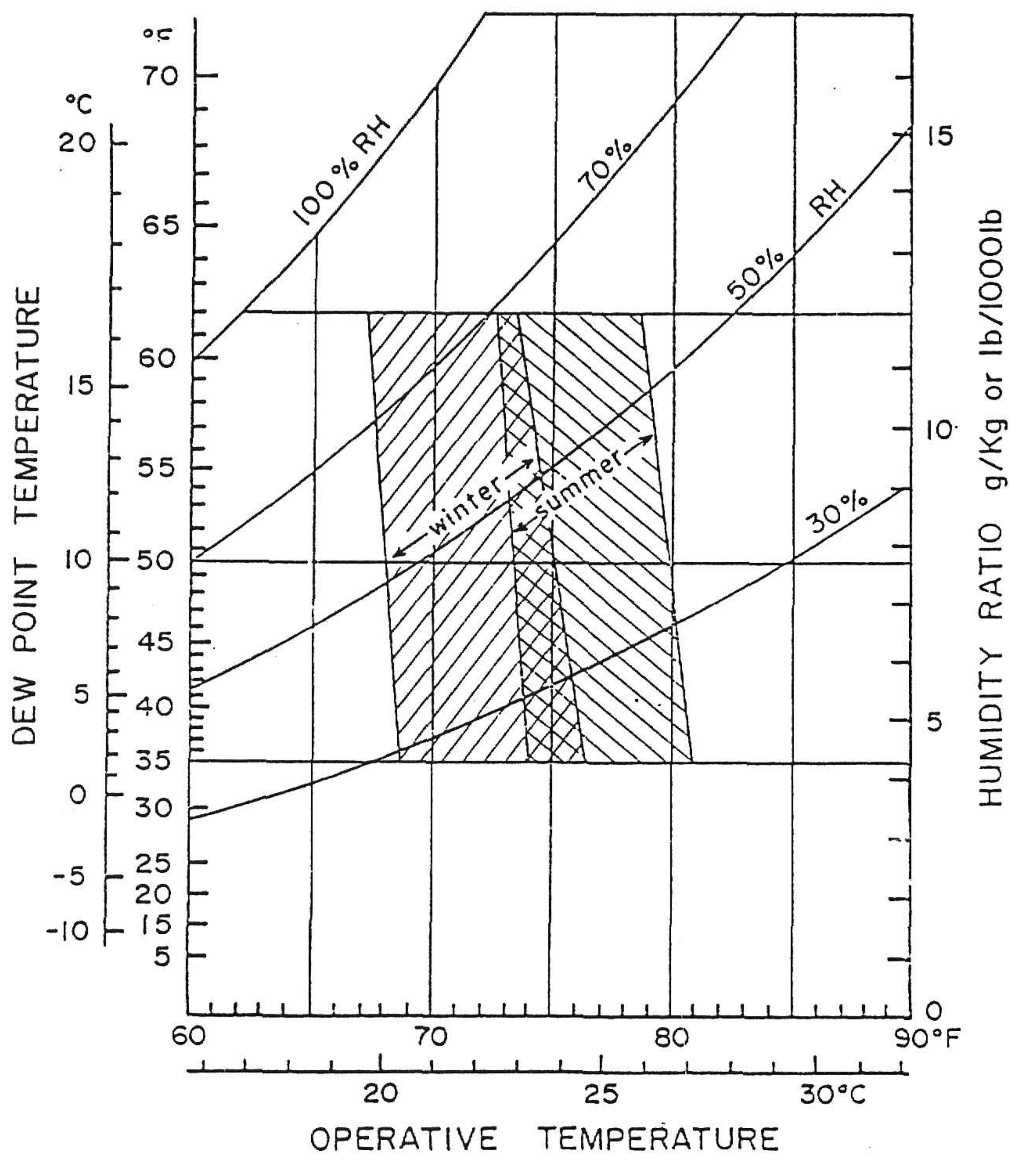

Figure 1: Acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light, mainly sedentary, activity. Reprinted by permission from ASHRAE Standard 55-1981.

The rate of activity has been incorporated into comfort charts by Fanger, and Nishi and Gagge (11,15,58), so if the activity of those occupying a room can be estimated the parameters to insure thermal comfort of the majority can be specified.

Also incorporated into these charts is the amount of clothing insulation worn. The "main physiological purpose" of clothing, as described by Madsen, is "to reduce the heat loss from the body just enough so that the body's internal heat production can be emitted to the environment while still maintaining thermal comfort" (49; p.2). The method of heat transfer from the skin to the environment through a single layer of fabric is very complex as described by Azer (4). Heat is transferred from the skin to the inner surface of the clothing by radiation and conduction through the trapped still air. Heat travels through the fabric itself by radiation from one fiber and yarn surface to another, by convection and conduction through the air in the fabric interstices, and by conduction through the fiber itself. This mechanism is impossible to measure and so is described as "the Apparent Thermal Conductivity" (4; p.88). Finally the heat is released from the fabric by convection and radiation to the environment. In order to study the effect of clothing on thermal response more easily, Gagge, Burton, and Bazett developed the clo unit (17). They define one clo as "the amount of insulation necessary to maintain comfort in a room at 21.1°C (70°F) with air movement not over ten feet per minute (0.10 m/sec) and humidity not over 50% with a metabolism of 50 calories per square meter per hour (resting)" (85; p.71, metric measurements added, see also 17,51). Adding one clo in the modal comfort envelope conditions is the equivalent of reducing the air temperature 7.2°C (13°F) without changing thermal sensation (76), or as Goldman calculates a 1°C (1.8°F) drop in air temperature can be compensated for by adding 0.2 clo (26).

The insulating value of clothing is measured on a copper manikin which very accurately determines clo values and so promotes reliability of experiments using standard clothing ensembles (4,51, 85,86). This method of measurement is based on the thermal equilibrium concept. The electrical power utilized by the manikin to stabilize its temperature must equal the amount of energy leaving the manikin through conduction, convection, and radiation (51). ASHRAE has compiled a list of clo values of typical clothing articles (see Table 1). Lists of this type can be referred to in estimating the clo value of almost any clothing ensemble.

The insulation value of fabrics in various environments depends upon the thickness of the fabric, the tightness of fit of the garment, the permeability of the fabric to air and water vapor, and the amount of air movement in the near environment. Fiber type is not a significant factor, as the various fiber's Apparent Thermal Conductivities and their resulting comfort are practically similar (4,52). The tightness of fit affects the dead air space created next to the body (4). It is this dead air space which is the actual insulator in cool weather by reducing heat lost through radiation and convection (95), thus clothing which is

Clo = 0.82 (Σ individual items)

MEN Clothing	clo	WOMEN Clothing	clo
Underwear			
Sleeveless	0.06	Bra and Panties	0.05
T Shirt	0.09	Half Slip	0.13
Briefs	0.05	Full Slip	0.19
Long underwear upper	0.10	Long underwear upper	0.10
Long underwear lower	0.10	Long underwear lower	0.10
Torso			
Shirt		Blouse	
Light, short sleeve	0.14	Light	0.20
long sleeve	0.22	Heavy	0.29
Heavy, short sleeve	0.25		
long sleeve	0.29	Dress	
(Plus 5% for tie or turtleneck)		Light	0.22
		Heavy	0.70
Vest		Skirt	
Light	0.15	Light	0.10
Heavy	0.29	Heavy	0.22
Trousers		Slacks	
Light	0.26	Light	0.26
Heavy	0.32	Heavy	0.44
Sweater		Sweater	
Light	0.20	Light	0.17
Heavy	0.37	Heavy	0.37
Jacket		Jacket	
Light	0.22	Light	0.17
Heavy	0.49	Heavy	0.37
Footwear			
Socks		Stockings	
Ankle Length	0.04	Any length	0.01
Knee High	0.10	Panty Hose	0.01
Shoes		Shoes	
Sandals	0.02	Sandals	0.02
Oxfords	0.04	Pumps	0.04
Boots	0.08	Boots	0.08

Table 1: Clo Units For Individual Items of Clothing and Formulae for Estimating Total Intrinsic Insulation. Reprinted by permission from ASHRAE Standard 55-1981.

tight produces cool discomfort at low temperatures. The construction characteristics of and finishes on the fabric affect the permeability of the fabric to air and water vapor (26). Because one-fourth to one-third of metabolic heat loss occurs through evaporation of perspiration, a fabric which is less permeable creates warm discomfort at high temperatures (4,85). Air movement, either through activity or through natural or artificial air motion, as measured by the pumping coefficient, also affects the insulation value of clothing (26). Increased air movement decreases dead air trapped by the clothing and so cools the body. In an office environment, where people are often seated, the clo value of a clothing ensemble is decreased because the weight of the seated person reduces the air space trapped between the clothing and the body (60), but the chair itself, by insulating parts of the body, may actually increase the feeling of warmth through a decreased air flow and trapped body heat. The permeability of the upholstery fabric used would affect the ability of the body perspiration to evaporate in the same way that clothing does.

An additional factor that has been examined in thermal response research is the differing reactions of men and women to environmental situations. Recent environmentally controlled research has resulted in conflicting findings on these differences. Fanger found "no significant difference in comfort conditions between males and females . . . and if any difference exists it is small and of no engineering significance" (14; p.87). McNall also found that men and women preferred similar neutral temperatures but that the comfort zone was wider for men (47). He attributed the women's greater sensitivity to their lower metabolic rate. McIntyre agreed that women are more sensitive to temperature changes either higher or lower than neutral (42), but that after two to three hours men and women adapt equally to the environmental temperature (43). Rohles, too, found that, although men adapted more quickly during the first hour, after two to three hours men and women tend to react similarly (72). Nevins, et al, also found men to adapt more quickly to temperature changes (55). Wyon, et al, noted that, although males had a significantly higher mean skin temperature and evaporative weight loss, there was no significant difference between male and female preferred air temperature (93). Conflicting results by Beshir and Ramsey recorded the male's preferred temperature at 22.0°C (71.6°F) while the female's preferred temperature was 25.0°C (77.1°F) (7). They attribute this finding to women's lower metabolic rate.

In field studies, Howell and Kennedy found that gender had little influence in predicting thermal comfort (36). The slight difference in thermal sensation found was explained in psychological terms: women were found to think of themselves as 'cold-natured' more often than men did. In office environments, Fishman and Pimbert found women to prefer a slightly lower temperature than men, possibly because they were more flexible in the amount of clothing that they wore (16). Much research has explored sex differences in thermal response but no certain generalizations can yet be made to describe men and women's reactions to their environments.

Other organismic and physical variables have been investigated as to their effect on thermal response. Although most environmental research has used college-aged people as subjects, several studies have compared them to the responses of the elderly and have found little difference (54,65,68). Fanger hypothesized that the lower metabolic rate of the elderly is compensated for by a lower evaporative loss (12). Children's responses to the environment have not yet been studied in depth and a need for research in this area has been noted (12). Although Nevins found significantly different results in morning and evening tests (57), later research has found that time of day has little effect on responses (15,16,42,48,71). In any case, this factor should be randomized or controlled to take into account any biological rhythmicity (57). Geographic area and season of the year have most often been found to have little effect (15,16,42,48,80). Some questions have been raised, however, as to the possible effect that seasonal variations in different areas of the world may have on thermal response (74). Differing thermal experience or clothing habits may be factors (14,74).

The length of the test is important in that it should simulate the applicable environment as closely as possible. The longer the exposure time the more the subject is able to adapt physiologically and psychologically to the change through sensory adaptation, "a sensory process in which the organism fails to perceive changes in the physical stimulus because of continuous stimulation" (67; p.99).

Psychological variables are also important to thermal response, contributing up to 10% of the total predictive variance (37). How people perceive their own cold-naturedness or tolerance as compared to others and what they perceive the temperature to be have been found to influence thermal response (37). A person's response has been found to be affected by the mere suggestion that the environmental temperature is different than it actually is (71).

Measures of Thermal Response

Physiological and subjective methods of evaluating thermal response have been used to measure the reactions of subjects. Various physiological responses have been measured and evaluated in the literature, but skin temperature has been recognized as a direct measure of physiological sensations of comfort (18,19,24,31, 84). Skin temperature relates especially well to cold sensations, but skin wettedness is a better predictor of warm discomfort (18,20). Thermal neutrality is achieved when the skin temperature is between 33.0°C (91.4°F) and 34.0°C (93.2°F) while the subject is sedentary with no sweating or shivering (15,18). A change of 2.5° - 3.0°C (4.5° - 5.4°F) is of great importance in evaluating comfort (31). Skin temperature is monitored by sensitive thermistors. Researchers have most commonly used either 15 (92) or 3 thermistors (84) and calculated a weighted mean skin temperature.

Although physiological measures are important, subjective measures of comfort are also necessary to fully understand thermal responses. Subjective comfort may change in response to some variables while the physiological responses remain constant (83). Three subjective measures have been developed: one each to measure thermal sensation, thermal comfort, and temperature preference. Thermal sensation is defined as the "conscious experience resulting from exposure to a group of variables making up the thermal environment" (67; p.98) and is most often measured with a 7-point scale. These 7-point scales to measure thermal sensation, first developed by Bedford in the 1930's, have been used, with modifications, extensively in environmental research (16,36,48). The ASHRAE scale lists the following categories for each subject to choose from: (67)

Hot	7
Warm	6
Slightly Warm	5
Neutral	4
Slightly Cool	3
Cool	2
Cold	1

Researchers have found that a one vote change on this scale is equal to a $3^{o}C$ ($6^{o}F$) change in temperature (46,47) and that the intervals are of equal widths, except for the two end categories, with a normal distribution (42,43). Thus parametric statistics can be used to find mean votes and to perform regression analysis to better understand trends in the data. Some error may possibly occur through variations in the subject's metabolism or mental state or through misunderstanding the scale, but for the most part the scale has been found to be very reliable (43,92). Recently, Rohles has added the categories of "very hot" and "very cold" to increase the scale to nine points (67). Because the end categories are not equal to the rest of the scale statistically and people usually do not choose the terminal categories to describe their sensations, the resulting scale actually has seven points. The extra categories are especially important for testing in extreme temperatures.

The second subjective scale measures thermal comfort, defined as the condition of mind which expresses satisfaction with the environment (2). A separate thermal comfort ballot is now administered along with the thermal sensation scale because the neutral temperature describing thermal sensation is not always the same as the comfortable or preferred temperature describing thermal comfort (43,45,74). A common scale used at Kansas State University has been developed by Rohles (67). It uses seven adjective pairs in a semantic differential format: comfortable - uncomfortable, bad temperature - good temperature, pleasant - unpleasant, cool - warm, unacceptable - acceptable, uncomfortable temperature - comfortable temperature, and satisfied - dissatisfied. The subject is asked to rank comfort feelings for each pair.

Rohles has added a temperature preference scale to be used along with the other scales to increase the reliability of subjective evaluations. It is composed of a temperature scale from $-10^{\circ}F$ to $+10^{\circ}F$ on which the subject marks the increase or decrease in temperature necessary to obtain the preferred environment.

Thermal Response in the Office Environment

Many of the findings of environmental research can be applied to thermal response in the office environment. Researchers have simulated office environments in the laboratory to study varying conditions. Nevins, et al, found that the slight activity of general office work (1.2 met) did not noticeably change the subject's preferred temperature for comfort, a temperature very close to that predicted by using Fanger's comfort equation (55). In a field study of 26 offices in various locations over a full year, Fishman and Pimbert surveyed the preferred temperature and clothing habits of male and female volunteers. They found that females preferred a slightly lower temperature, 21.7°C (71.1°F), as compared to men, 22.0°C (71.6°F), and were more flexible in their clothing habits (16). When studying the effect of furnishings, as compared to a bare room, Rohles found that the furnishings themselves led the subjects to feel psychologically, but not physiologically, warmer (83). Ideal office temperatures as determined by the ASHRAE 1981 Comfort Zone in winter are 20.0°-23.6°C (68°-74.5°F) ET* at 50% relative humidity with heavy clothing of 0.9 clo: heavy slacks, long sleeve shirt, and sweater. In summer the temperature increases to 22.8°-26.1°C (73°-79°F) ET* at 50% relative humidity with light clothing of 0.5 clo: light slacks and short sleeve shirt (2).

The effect of temperature on performance of office work has also been examined. Langkilde studied 15 females in a series of 15 - seven hour simulated office days at five temperatures in the range 18° - 30°C (64.4° - 86°F). She found "performance of normal office work only slightly affected by ambient temperature" (41; p.853). Nevins found decreased manual and mental performance with increasing temperatures over 27.2°CET (81.0°FET) (54). At lower temperatures mental performance of sedentary subjects, as tested by Wyon, et al, was not significantly different at 18.7°C (65.7°F) in 1.15 clo and at 23.2°C (73.8°F) in 0.6 clo. Average skin temperature also remained stable in these conditions (93). In temperatures recommended to conserve energy, 20.0°C (68°F), subjects at a 400-500 BTU activity level in 0.6 clo had an equal or better performance, even though they felt cold or slightly cool, than at 25.6°C (78°F) and 28.9°C (84°F) in which the majority felt neutral (62).

Chair comfort, also important to workers according to the Steelcase/Harris survey, may affect productivity, absenteeism, and illness (50). There are conflicting views on the magnitude of the effect on productivity. E.R. Tichaur, a human factors professor at New York University, believes that 40 additional productive minutes a day could be achieved through the use of a well-constructed chair. However, Charles Mauro, a human factors consultant, is sceptical, "within a wide range, (a) better (chair) doesn't help". Industrial designer William Stumpf is also less optimistic in believing that productivity could be increased "a questionable one percent" (38; p.126). Poorly designed chairs can contribute to back disorders, the second highest cause of absenteeism in the office, especially in those seated all day in front of the ever increasing number of computer display terminals (38).

The covering on the chair may also cause discomfort. Dr. Jeanne M. Stellman, author and expert on occupational health, recommends fabrics that breath to let body heat and perspiration dissipate, especially when synthetics used in clothing keep perspiration from evaporating. In the extreme she says, "some experts even think that this daily build up of heat and moisture can cause such medical problems as bladder infection or vaginitus" (50; p.61). Effects are not always this extreme, but comfort is affected by the covering. Garrow and Wooller also stress the importance of moisture dissipation and hygroscopicity of fibers used because ". . . it is well known that sitting on the impervious plastic upholstery material . . . can by uncomfortable, particularly in warm weather" (25; p.255). They found that an overlay of sheepskin increased the comfort in automobiles with vinyl upholstery but had no effect on comfort in those with more luxurious coverings. Grandjean, et al, recommend upholstery with 2 - 4 cm of padding to increase comfort by the distribution of pressure points and increased slide resistance. The material recommended should allow air circulation, should be rough rather than slippery, should conserve heat, and should be somewhat elastic and soft (30). Recently, chair comfort as related to chair covering was evaluated by Rohles and Krohn. They found that cloth covered chairs contributed to a higher thermal comfort than vinyl covered chairs at 25.6°C (78°F) and 50% relative humidity (77).

Chair comfort has been evaluated in a variety of ways, but "no general agreement on one or a few techniques of proven adequacy, precision, and reliability" has been widely accepted (87; p.170). Comfort is a nebulous concept which must be measured with psychophysical methods, rather than in physical units (87). Shackel, Chidsey, and Shipley recommend a combination of the following comparative measurements to evaluate chair comfort: 1) anatomical and physiological factors, 2) observations of body positions and movement, 3) observation of task performance, and, primarily, 4) subjective controlled methods (87). They developed an 11 item comfort rating scale with 10 unequal, but relatively consistant, intervals. These 10 items were chosen from a larger list in a pre-test, but not further tested or refined. A vertical line drawn beside the scale allows the subject to choose their feelings along a continuum. When scored at every half level, 20 scores result in the discriminating scale illustrated below: (87; p.275)

Please rate the chair on your feelings now:

- I feel completely relaxed
- I feel perfectly comfortable
- I feel quite comfortable
- I feel barely comfortable
- I feel uncomfortable
- I feel restless and fidgety
- I feel cramped
- I feel stiff
- I feel numb (or pins and needles)
- I feel sore and tender
- I feel unbearable pain

They recommend improvement of this scale, especially on the comfortable end, and further validation, but the scale has been used, as developed, by other researchers in more recent chair comfort studies (10). Other subjective ratings of chairs include body area comfort ratings (87), a chair feature checklist (87), and direct ranking (87), but these evaluate general comfort rather than thermal comfort or chair covering. In lengthy tests, chair comfort ratings were found to decrease with time, especially noticeable in poor chairs, but less noticeable in office environments where workers leave their chairs periodically (87). Drury and Coury evaluated general chair comfort with the previously illustrated scale (10). Covering of the chairs was not directly evaluated, but the additional comments of one of the subjects indicated a positive feeling in a cloth covered chair. Rohles and Krohn developed a semantic differential chair attribute scale which evaluated chair style, chair size, and nonthermal chair comfort (77). Nonthermal chair comfort has been evaluated more extensively than thermal comfort of chairs has.

Office workers feel that both the right temperature and a comfortable chair are important to job comfort. It has been found that normal office temperatures can be acceptible to employees for comfort and to employers for performance standards. Nonthermal comfort has been evaluated more often than thermal comfort of chairs has, but chair covering has been found to affect thermal comfort. The permeability of the fabric to moisture would seem to have the greatest effect on thermal comfort at high temperatures because of increased skin wettedness, but it is unknown what differences, if any, exist between cloth and vinyl covered chairs at lower temperatures.

Chapter 3

METHODOLOGY

Research Design

The purpose of this research study was to investigate the effect of four different chair models, each with two coverings, on the thermal response, and the perception of chair attributes, of women at 20.0°C (68°F) ET*, 22.8°C (73°F) ET*, and 26.1°C (79°F) ET* at four successive time periods. This 4 x 2 x 3 x 4 factorial design (see Table 2) permitted the testing of a variety of objectives, including those concerning the interaction of the independent variables on thermal response. The scheme of the design included 24 cells with six subjects per cell. Thus 144 subjects would be tested.

In this two-part study the dependent variables under investigation were thermal response and perceived chair attributes. Thermal response was determined by subjective thermal sensation, temperature preference, and thermal comfort ratings. Chair stylishness, chair size, and chair comfort as perceived by the subjects were determined by the 17 adjective-pair Chair Attribute Scale.

Four independent variables were systematically varied. The first was chair design, with four levels. Three of the chair models, the Executive model, the Manager model and the Conference

Table 2: Research Design

	Cloth Upholstery					Vinyl Upholstery			
Chair Model[a]	E	M	C	T		E	M	C	T
Temperature:	1	2	3	4	Subject[b]	5	6	7	8
	25	26	27	28	Number:	29	30	31	32
20.0°C	49	50	51	52		53	54	55	56
	73	74	75	76		77	78	79	80
(68°F)	97	98	99	100		101	102	103	104
	121	122	123	124		125	126	127	128
	9	10	11	12		13	14	15	16
22.8°C	33	34	35	36		37	38	39	40
	57	58	59	60		61	62	63	64
(73°F)	81	82	83	84		85	86	87	88
	105	106	107	108		109	110	111	112
	129	130	131	132		133	134	135	136
	17	18	19	20		21	22	23	24
26.1°C	41	42	43	44		45	46	47	48
	65	66	67	68		69	70	71	72
(79°F)	89	90	91	92		93	94	95	96
	113	114	115	116		117	118	119	120
	137	138	139	140		141	142	143	144

[a] E: Executive, M: Manager, C: Conference, T: Concentric

[b] Each subject responded to the environmental conditions four times in two hours, to the chair attributes two times in two hours.

model, were specified based on previous research in which subjects judged the chairs to be equally stylish and comfortable according to the Chair Attribute Scale (77). An additional model, the Concentric model, was also rated in this study. Unlike the other models it could be adjusted: the chair height could be controlled, the angle of the seat could be varied, the chair could be set so it could not be tilted, and the amount of support in the lower back region could be controlled. (This was explained to the subjects after they were seated in the chairs and were ready to begin the testing session. Each individual seated in the Concentric model was then allowed to adjust the chair for comfort whenever necessary throughout the test). All chairs were supplied by Steelcase (see Figure 2 and Table 3).

The second independent variable was type of upholstery fabric used as a covering on each chair. Two chairs of each style were tested - one covered in a heavy, plain weave, cloth fabric and one covered in a smooth vinyl fabric. Each fabric, each in various colors, was representative of that commonly used for office furniture.

The third independent variable was temperature. Three temperatures were specified to simulate a minimally air-conditioned summer office environment (26.1^{o}C/79^{o}F ET*), a neutral office environment (22.8^{o}C/73^{o}F ET*), and a minimally heated winter office environment (20.0^{o}C/68^{o}F ET*). These correspond to the edges of ASHRAE's recommended comfort zone for winter and summer for sedentary, typically clothed people (2) (see Figure 1, p.15).

Table 3

Dimensions of Chair Models:

Chair Model	Dimension, mm Back Height	Seat Width	Seat Depth
Executive	640	521	490
Conference	470	491	430
Manager	470	501	445
Concentric	465	465	460

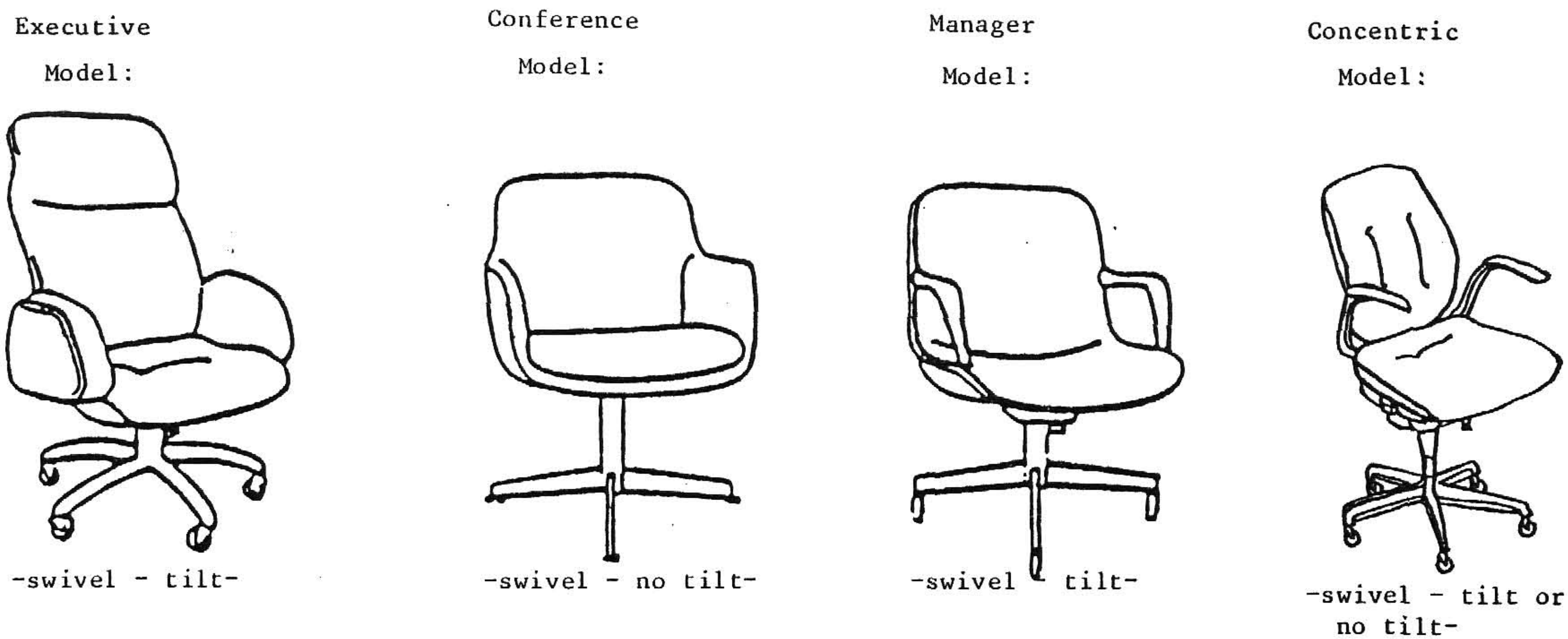

Figure 2: Line drawings and design characteristics of the four chair models

The fourth independent variable was the passage of time. Subjects were asked to respond to their thermal environment at the end of each half hour of testing throughout the two hour period, for a total of four sets of responses. In a similar manner, the subjects responded to the Chair Attribute Scale at the end of each hour of testing for a total of two sets of responses from each subject during the two hour test session.

Environmental Chamber Environment

The testing was conducted in the KSU-ASHRAE Environmental Test Chamber located in Kansas State University's Institute for Environmental Research. The actual tests took place in the main chamber which is 12 ft wide, 24 ft long, with a 10 ft ceiling. The walls were covered with dark brown paneling and the floor with an orange low level loop carpet. Five tables were in the room to compose the nine test stations: eight for the test subjects, one for the experimenter. Each of the four tables for the subjects' stations held two study lamps which provided task lighting from a single fluorescent 46 cm (18 in.) 15 w bulb. Additional lighting was provided from wall valence fluorescent lights from four 1.2 m (4 ft) 30 w fluorescent bulbs. The foot candle measurements at the test stations varied from 78 - 65 f.c. on the tables directly under the study lamps to 55 - 30 f.c. on the edge of the table surface. Relative humidity was maintained at 50%. The dry bulb temperature in the chamber was maintained at either 20.0°C (68°F), 22.8°C (73°F), or 26.1°C (79°F) throughout the test.

Mean radiant temperature was held constant at the test air temperature and air movement was less than 0.15 meter per second (30 ft/min.). The eight chairs were arranged randomly at the eight stations. The subjects were tested at a sedentary (1 met) activity level.

The pretest orientation and conditioning was conducted in a 9 x 10 ft room, furnished with eight padded straight chairs and a desk, adjacent to the chamber. Conditions were stable throughout the conditioning period which lasted approximately 20 minutes before each test session.

Clothing

The clothing selected was chosen to provide comfort according to the ASHRAE Standard (2) (see Figure 3) and previous research by Holzle at Kansas State University (32). Most of the clothing used in this study had been used in the Holzle research and tested for clo value on the copper manikin. At 26.1°C (79°F) ET* the subjects were given the summer light weight ensemble which consisted of 1) a light weight light blue, short sleeve broadcloth shirt, 2) medium weight bright blue, poplin pants, 3) white knit socks, and 4) sandals, for a total of 0.56 clo. Although 0.56 clo is at the upper acceptability limit, in an office environment the wearing of fewer clothes would not be socially acceptable. At 22.8°C (73°F) ET* the subjects wore the medium weight ensemble which consisted of 1) a medium weight, light blue, long sleeve oxford cloth shirt, 2) medium weight light blue gabardine pants, 3) a medium weight light blue, lined, gabardine

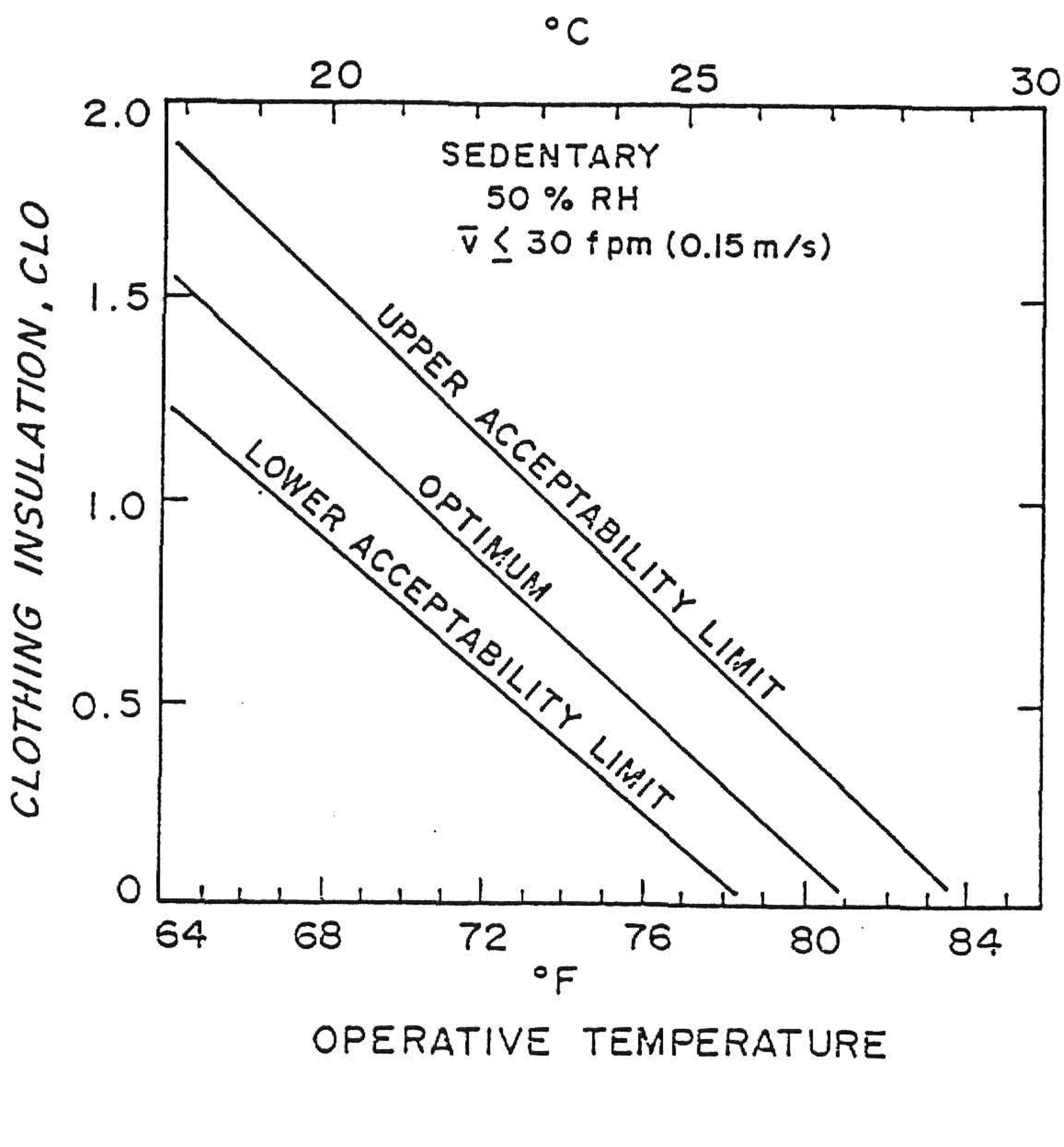

Figure 3: Clothing insulation necessary for various levels of comfort at a given temperature during light, mainly sedentary activities. Reprinted by permission from ASHRAE Standard 55-1981.

blazer, 4) white knit socks, and 5) soft soled, cloth shoes provided by the subject for a total of 0.95 clo. At 20.0°C (68°F) ET* the subjects were given, in addition to the 0.95 clo ensemble described above, a navy blue, v-neck, long-sleeved, cable front, 100% acrylic sweater in order to bring the clo value into the lower acceptability range. This ensemble then totaled 1.06 clo as measured on a standing copper manikin. In addition to the ensemble given to the subjects, each wore her own bra and underpants.

The blazers were commercially dry-cleaned weekly during the testing period. The remaining clothing was laundered after each session as necessary. This was done in the Clothing, Textiles and Interior Design department of Kansas State University's College of Home Economics by the experimenter.

Population

A total of one-hundred-forty-four female subjects, age 18 to 25 were recruited from the student body of Kansas State University from general psychology courses and through a newspaper advertisement. Volunteers from the general psychology courses were recruited with an announcement on the psychology department's experiment information table (see appendix). These students were given two hours of experimental credit for their participation in the study. Because an insufficient number of students was available through the psychology classes, a newspaper advertisement was run for one week in the Kansas State Collegian to recruit the additional subjects.

These subjects were paid $7.00 for their participation. Approximately 1/3 of the subjects were recruited through the psychology department; approximately 2/3 from the newspaper advertisements.

Those that were interested in participating came to a sign-up area in the Institute for Environmental Research. There they read a Recruitment Orientation Statement (see appendix). After deciding to participate, the subject filled out an information form giving her name, address, and clothing sizes. This was done so that the subject could be contacted and to assure that those signing up for each session would have clothing that fit because there were only a limited number of ensembles in each size available. The subject then signed up for a convenient test time, and was given an assignment form to remind her of her test time (see appendix). The subjects were randomly assigned to test groups and the treatment of the groups was random. All treatment of the subjects conformed to the regulations of human subject research as required by Federal Regulations and University policy.

Procedure

The testing was conducted in a three week and one day period from March 21 through April 11, 1983. There were three morning sessions, on Tuesday, Thursday, and Friday from 9:30 - 12:00 A.M., and four evening sessions, on Monday, Tuesday, Wednesday, and Thursday from 6:30 - 9:00 P.M., each week.

A pilot test session was conducted on March 10, 1983, to assure that there was sufficient time for pretesting and testing and to become familiarized with the precedure. Twenty-two sessions, rather than the 18 needed to test a total of 144 subjects, were scheduled in order to accomodate subjects that failed to arrive for the test. It was decided that if less than five subjects arrived for the session it would be cancelled. None of the sessions, however, had to be cancelled.

Temperatures were changed randomly, but were held constant for each entire day of testing.

On the evening before each test session each subject was telephoned to confirm her participation in the test and to remind her to wear or bring her own soft-soled shoes. When the subjects arrived for the session they were asked to don the appropriate clothing ensemble, and then asked to report to the pretest room. An assistant then took their temperatures to assure that they were healthy with a temperature of $98.6 \pm 1^{\circ}F$. If it was not, the subject was allowed to participate, but that subject's data were not used in analysis. The subjects were made aware of their rights by reading and signing two copies of the Agreement and Release Form (see appendix), one for their records, one for our records. While still in the pretest room the subjects were read the following orientation statement by the experimenter informing them of the purpose, procedure, and rules of the study:

Orientation Statement

The purpose of this study is to determine how people respond to their thermal environment. You should be fully aware that the conditions to which you will be exposed entail no physical risks. Second, you have volunteered to act as a subject and are participating on your own volition. Third, you may stop participating in the experiment if necessary. Fourth, your identity as a subject will not be disclosed and your anonymity will be maintained.

The way the test will proceed is this: soon you will be taken into the test room next to us where you will remain for two hours. While there you will be studying or reading and filling out test ballots. You may not talk, communicate with each other in any manner, sleep, walk about, or leave the room during the test. I will be present throughout the test to announce when to fill out ballots and collect them. Water, Kleenex, and magazines are available on a table in the test room.

Each of you should have a clipboard. You should have signed both copies of the Agreement and Release Form. You may keep one for your records. You should have examples of the four test ballots you will be using on your clipboard. (Read directions and first example, wait, and read last pointers). Do you have any questions? You will be completing a thermal comfort ballot, a thermal sensation ballot, and a temperature preference ballot every half hour and a chair comfort ballot every hour. When you complete the fourth or last set of ballots, the test will be finished.

Are there any questions?

When you follow me into the test room, you will be shown where to sit. When everyone is seated the test will begin.

The subjects were then lead into the test chamber and allowed to sit where they desired. The ballots on the tables, including the three computer cards (see appendix), the chair comfort ballot, and a set of directions, were pointed out to the subjects. The adjustments of the two Concentric chairs were explained to the two subjects seated in them. The two-hour exposure period then began.

Environmental conditions were monitored continually and the ballots were taken periodically as described. When two hours has passed the subjects were read the following debriefing statement, paid if necessary, and allowed to change into their own clothing and leave.

Debriefing Statement

Thank you for participating in this experiment. We should have some results in about six weeks. Since I have your names and addresses I will send you a summary of the results if you are interested. Please make a note on the chair comfort ballot if you are. Thank you again.

Data Analysis

The subjective measures of thermal sensation, thermal comfort, temperature preference, and chair attributes were treated by analysis of variance for the main effects and interactions. Fisher's Least Significant Difference Test was used to determine which effects and interactions were significant. Statistical tests were conducted at the 0.05 level of significance. A description of the results of these analyses are described in Chapter 4.

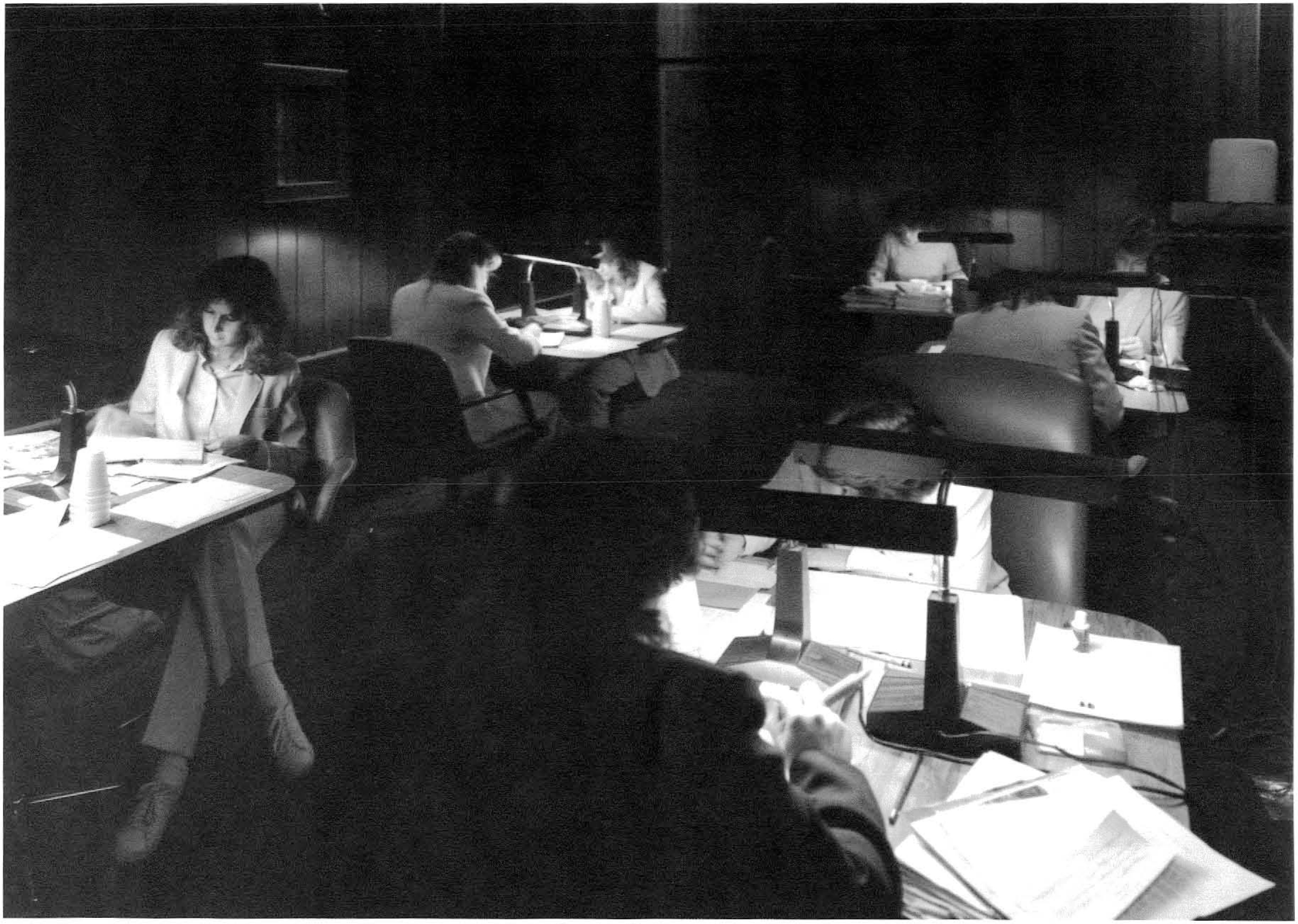

Figure 4: View of test chamber at 22.8^{O}C (73^{O}F) ET*

Chapter 4

RESULTS AND DISCUSSION

A four-way analysis of variance, with repeated measures with respect to time, was used to test for differences in the main effects and interactions of four factors, 1) temperature, 2) chair model, 3) chair covering, and 4) time passage, on the subjective thermal responses of college-aged women. In addition, the effects of these four factors on the women's perceptions of the chair attributes were analyzed. The subjective thermal response was measured by three scales: thermal comfort score, thermal sensation score, and temperature preference vote. The chair stylishness, size, and comfort were measured by the subjective Chair Attribute Scale. Post hoc analysis used Fisher's Least Significant Difference (LSD) test to find the significant differences between the means of the main effects as well as the two-way and three-way interactions.

In order to have a complete set of data one replication at each temperature was included as a make-up test. These data were used to substitute for missing or unusable data from previous tests resulting from absent subjects, body temperatures outside of the $98.6 \pm 1^{o}F$ range, and unusual behavior by the subjects, such as having to leave the room for a period of time. Final analysis was performed on data from 143 subjects for a total of six replications of each testing situation except one, for which there were only five replications completed. The exception occurred on the data set composed of the vinyl covered Conference chair at 26.1°C (79°F) ET*.

The analysis of the six scales evaluating the variables, i.e., thermal comfort score, thermal sensation score, temperature preference vote, chair stylishness, chair size, and chair comfort, follow.

Thermal Comfort Score

Thermal comfort scores were tallied from the seven adjective-pair thermal comfort scale. The pair cool-warm was not included in the analysis because it has been questioned if this pair of adjectives can be ranked from most desirable to least desirable as the other pairs are for the purposes of weighting, so the scale used here had a total of six adjective pairs. Between each adjective pair were nine spaces which formed a continuum for the subject to describe her feelings. The more desirable of the pair was ranked nine, the neutral middle was ranked five, and the least desirable term ranked one. Weightings were computed by a statistical scaling technique developed by Rohles and Milliken (79) to be used to develop unique weighting factors according to the individual variables in each type of testing situation. The following loadings resulted: comfortable - uncomfortable, 0.90856; good temperature - bad temperature, 0.96168; pleasant - unpleasant, 0.94394; acceptable - unacceptable, 0.95152; satisfied - dissatisfied, 0.95622, and comfortable temperature - uncomfortable temperature, 0.96345. Each set of six pairings was weighted and summed to produce a score describing thermal comfort;

the higher score indicating more comfort. This thermal comfort score can then be expressed in a percentage form if desired (79).

No significant differences in the thermal comfort means were found at the 0.05 level, the thermal comfort percentage ranging from just below to just above 70%. The analysis of variance is summarized in Table 4. These results could be explained because the subjects were dressed in the recommended clothing insulation for comfort at temperatures within ASHRAE's recommended winter and summer comfort zones for a sedentary activity level (2).

These results do, however, differ from those found by Rohles and Krohn (77). They found that thermal comfort was significantly affected by chair covering at 25.6°C (78°F) at 50% rh, only one degree Fahrenheit lower than the highest temperature tested in the present study. They found that those subjects seated in cloth-covered chairs judged their thermal comfort to be higher than those seated in vinyl-covered chairs. This difference could be attributed to differences in the testing situation, namely, the use of both males and females, the use of the K-State uniform totaling 0.6 clo which is slightly higher than the 0.56 clo worn here, the different weightings derived in their study, and the larger number of subjects per testing situation - twelve vs our six - that Rohles and Krohn were able to involve. Their study used the seven adjective-pair thermal comfort ballot while the present study used the six adjective-pair ballot. The present findings suggest that there is little difference in thermal comfort ratings due to chair covering at lower temperatures.

Table 4: Analysis of Variance of Thermal Comfort Scores

Source	df	SS	F-value*	pr>F
Error (model)	357	17,914.15		
Error (Rep (Temperature))	15	2,800.28		
Temperature	2	1,098.47	2.94	0.0836
Error (Rep x Model X Cover (Temp))	104	38,009.20		
Model	3	190.81	0.17	0.9113
Cover	1	215.02	0.59	0.4448
Model x Cover	3	994.51	0.91	0.4423
Model x Temperature	6	1,518.94	0.69	0.6560
Temperature x Cover	2	894.08	1.22	0.2985
Model x Temperature x Cover	6	1,301.60	0.59	0.7348
Time	3	355.37	2.36	0.0699
Temperature x Time	6	106.59	0.35	0.9074
Model x Time	9	304.08	0.67	0.7345
Cover x Time	3	217.53	1.45	0.2281
Model x Temperature x Time	18	769.62	0.85	0.6378
Temperature x Cover x Time	6	258.80	0.86	0.5248
Model x Cover x Time	9	186.86	0.41	0.9275
Model x Temperature x Cover x Time	18	866.27	0.96	0.5071

*None of the F-ratios was significant at p .05.

Thermal Sensation

The thermal sensation ballot consists of a continuum of nine terms describing thermal sensations that the subjects used to rate how they felt after 30, 60, 90, and 120 minutes. The terms and their respective scoring were: very cold - 1, cold - 2, cool - 3, slighly cool - 4, neutral - 5, slightly warm - 6, warm - 7, hot - 8, and very hot - 9. These scorings were subjected to an analysis of variance to find the effects of temperature, chair model, chair covering, and time passage, and their interactions. Where significant F-values appeared the means were subjected to Fisher's Least Significant Differences Test.

Significant differences were found at the main effect level for temperature and time. These effects are analyzed and summarized in Table 5 and Figures 5 and 6.

It was found that the thermal sensation score was significantly different at each temperature, even with the recommended clothing changed to compensate for the difference in temperature. The direct relationship between thermal sensation and temperature infers that the subjects tested at the higher temperatures felt warmer than the subjects tested at lower temperatures. At the 0.05 level each temperature showed a significantly different thermal sensation score.

The seemingly large range of thermal sensation scores, even when clothing was worn to compensate for temperature differences, could be explained by the position of the clo values chosen on

Table 5: Analysis of Variance of Thermal Sensation Ratings

Source	df	SS	F-value	pr>F
Error (model)	357	197.50		
Error (Rep (Temperature))	15	72.12		
Temperature	2	99.33	10.33	0.0015
Error (Rep x Model x Cover (Temp))	104	273.58		
Model	3	15.82	2.00	0.1163
Cover	1	0.02	0.01	0.9229
Model x Cover	3	0.67	0.08	0.9630
Model x Temperature	6	15.61	0.99	0.4367
Temperature x Cover	2	1.59	0.30	0.7404
Model x Temperature x Cover	6	6.74	0.43	0.8594
Time	3	4.33	2.61	0.0506
Temperature x Time	6	4.58	1.38	0.2223
Model x Time	9	6.98	1.40	0.1847
Cover x Time	3	3.82	2.30	0.0753
Model x Temperature x Time	18	8.38	0.84	0.6502
Temperature x Cover x Time	6	2.94	0.89	0.5049
Model x Cover x Time	9	5.57	1.12	0.3481
Model x Temperature x Cover x Time	18	10.65	1.07	0.3820

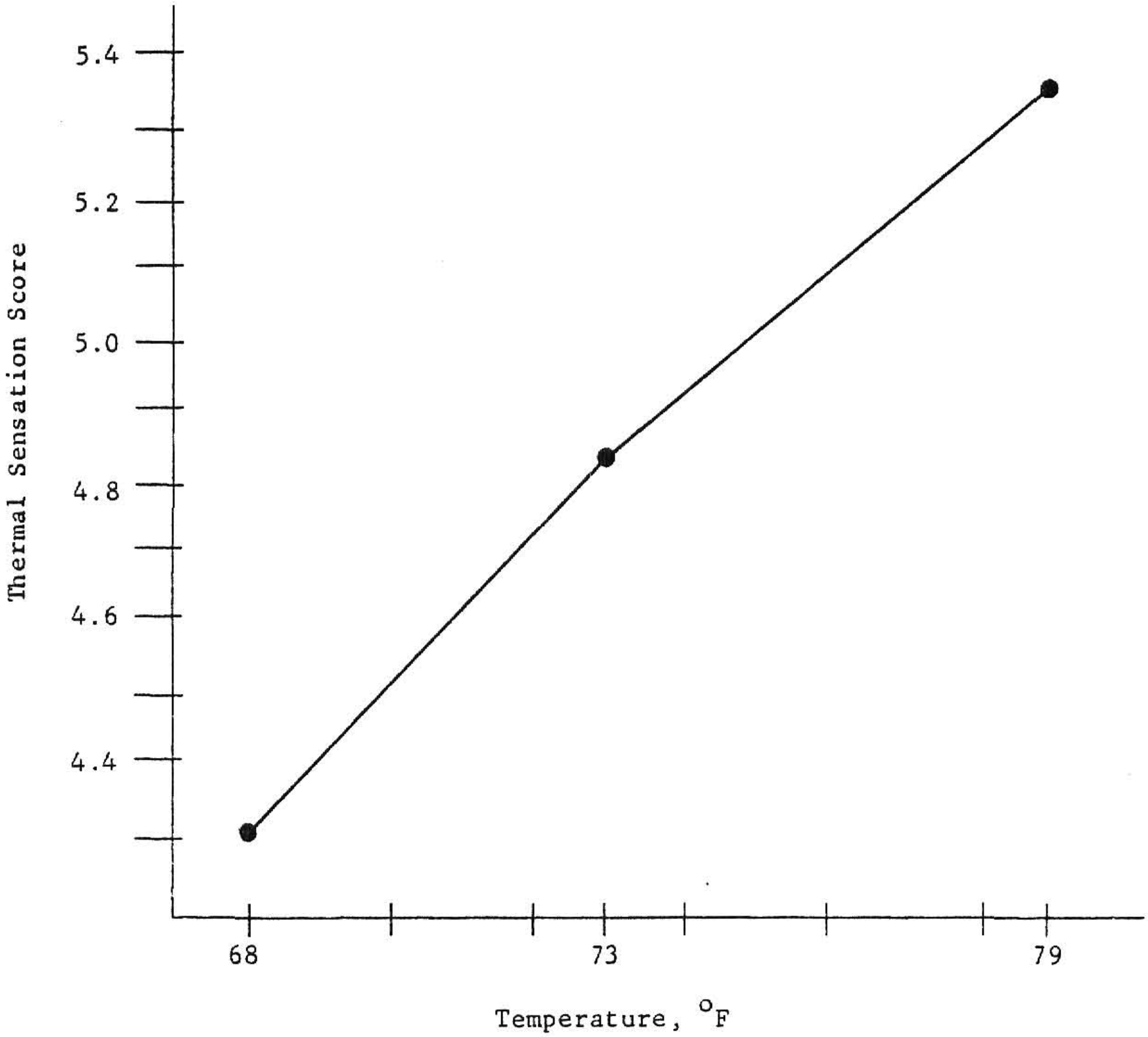

Figure 5: Thermal sensation means at three environmental temperatures.

Separation of means: Thermal Sensation

LSD = 0.470 at 5%

Temperature, °F		
68	73	79
4.307	4.802	5.330

Those means with common underlines are not significantly different at 5%.

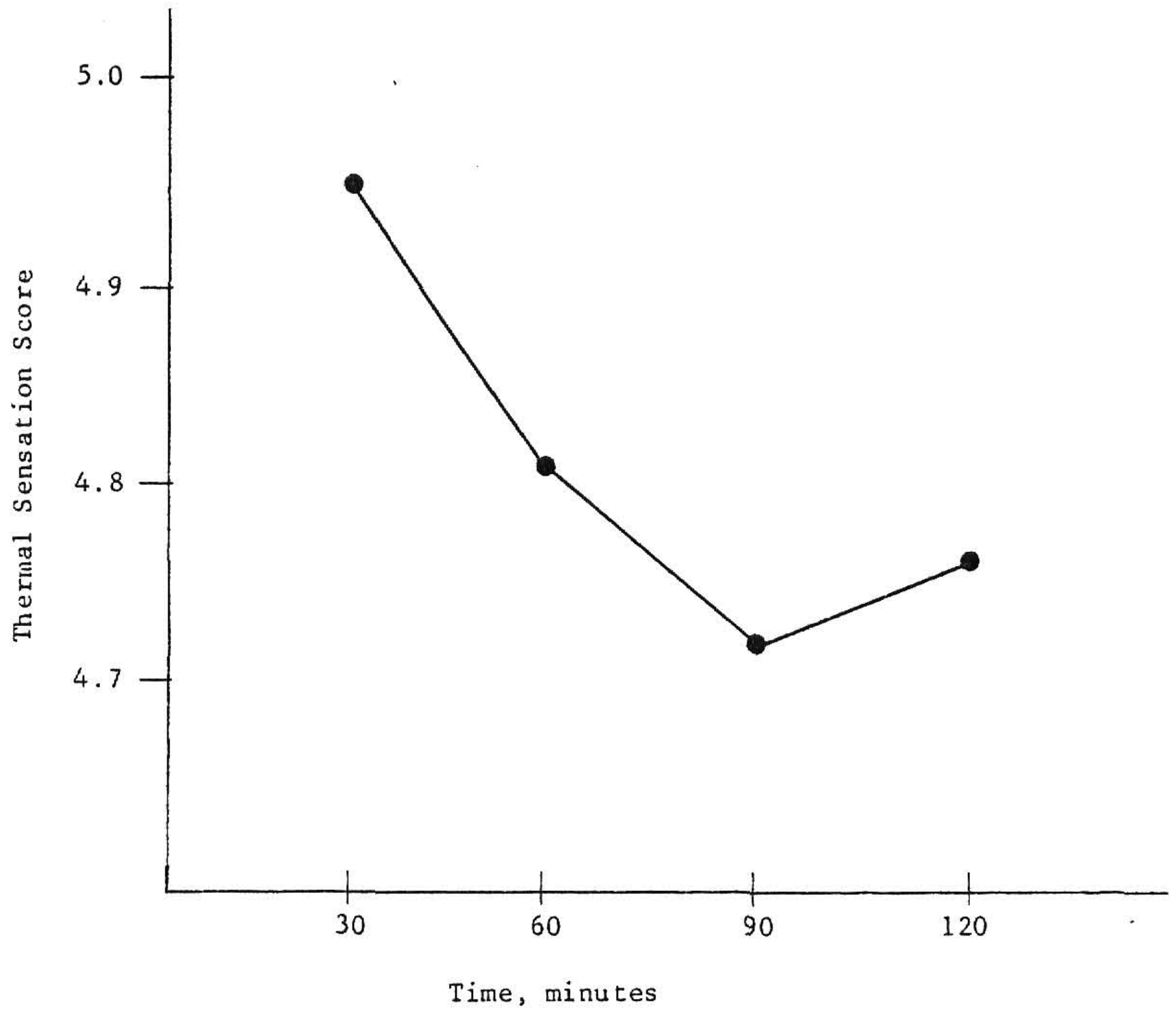

Figure 6: Thermal sensation means over time.

Separation of means: Thermal Sensation

LSD = 0.174 at 5%

Time, minutes

30	60	120	90
4.951	4.804	4.762	4.721

Those means with common underlines are not significantly different at 5%.

ASHRAE's recommended clothing insulation graph (see Figure 3, p.37). Although 0.95 clo was near the optimum level for 22.8°C (73°F), the 0.56 clo at 26.1°C (79°F) and the 1.06 clo at 20.0°C (68°F) were close to the upper and lower acceptability limits, respectively.

The range of thermal sensation means do, however, fall into ASHRAE's acceptibility limits which include those votes near slightly warm and slightly cool, from a vote of 4 to a vote of 6 on the thermal sensation scale (2). Thus, this range of votes does not contradict the previous findings of stable thermal comfort scores at all temperatures. The difference in temperature is sensed, but is not extreme enough to be judged uncomfortable.

At the main effect of time it was found that the subjects, at all temperatures, in all the chair models and coverings, felt cooler with time. The subjects felt almost neutral initially, at 30 minutes, while at 90 and 120 minutes they felt significantly cooler. The subjects were sedentary so this cooling with time is logical, especially at the lower temperatures. This finding agrees with previous research by Rohles and Nevins (80) who also found a decrease in the thermal sensation votes with time. The magnitude of the change in vote over two hours is similar to the present study, but the mean thermal sensation scores in the present study were slightly cooler than those found for women in the Rohles, Nevins study. That large study used the 7-point scale, while the 9-point scale was used in the present smaller study which could explain some of this difference. A similar effect of time on thermal comfort was found at a 0.07 level of significance, not far from the 0.05 level required for acceptance here.

Temperature Preference

The temperature preferences of the subjects were scored from the Temperature Preference continuum which lists the temperatures +10°F to -10°F in 1°F increments on which the subject marked the number of degrees higher or lower she would turn a thermostat to become more comfortable. The data were analyzed at the values of -10 to +10 in an analysis of variance to find the effects of temperature, chair model, chair covering, and time, and their interactions. Where significant effects were found Fisher's LSD test was used to separate the means.

An interaction between time and temperature was found to be significant. The effects are described and analyzed in Tables 6 and 7 and in Figure 7.

The analysis showed that after two hours at 26.1°C (79°F) ET* the subjects preferred the temperature to be lower, and at 30, 60, and 90 minutes at 20.0°C (68°F) ET* the subjects preferred the temperature to be higher to be satisfied with their environment. When the temperatures are compared over time it was found that at 26.1°C (79°F) ET* the temperature preference remained constant at approximately -0.6°F. At 22.8°C (73°F) ET* the subjects preferred the temperature to be lower in the first hour of testing and higher during the second hour of testing. At 20.0°C (68°F) ET* the subjects initially preferred the temperature to be slightly

Table 6: Analysis of Variance of Temperature Preference

Source	df	SS	F-value	pr>F
Error (model)	357	743.92		
Error (Rep (Temperature))	15	389.56		
Temperature	2	309.61	5.96	0.0124
Error (Rep x Model x Cover (Temp))	104	1,609.90		
Model	3	33.84	0.69	0.5615
Cover	1	0.01	0.00	0.9836
Model x Cover	3	64.51	1.32	0.2703
Model x Temperature	6	62.66	0.64	0.6961
Temperature x Cover	2	8.43	0.26	0.7720
Model x Temperature x Cover	6	64.98	0.67	0.6772
Time	3	46.51	7.44	0.0001
Temperature x Time	6	32.23	2.58	0.0186
Model x Time	9	9.78	0.52	0.8596
Cover x Time	3	7.01	1.12	0.3403
Model x Temperature x Time	18	26.35	0.70	0.8089
Temperature x Cover x Time	6	20.09	1.61	0.1441
Model x Cover x Time	9	16.12	0.86	0.5628
Model x Temperature x Cover x Time	18	33.75	0.90	0.5793

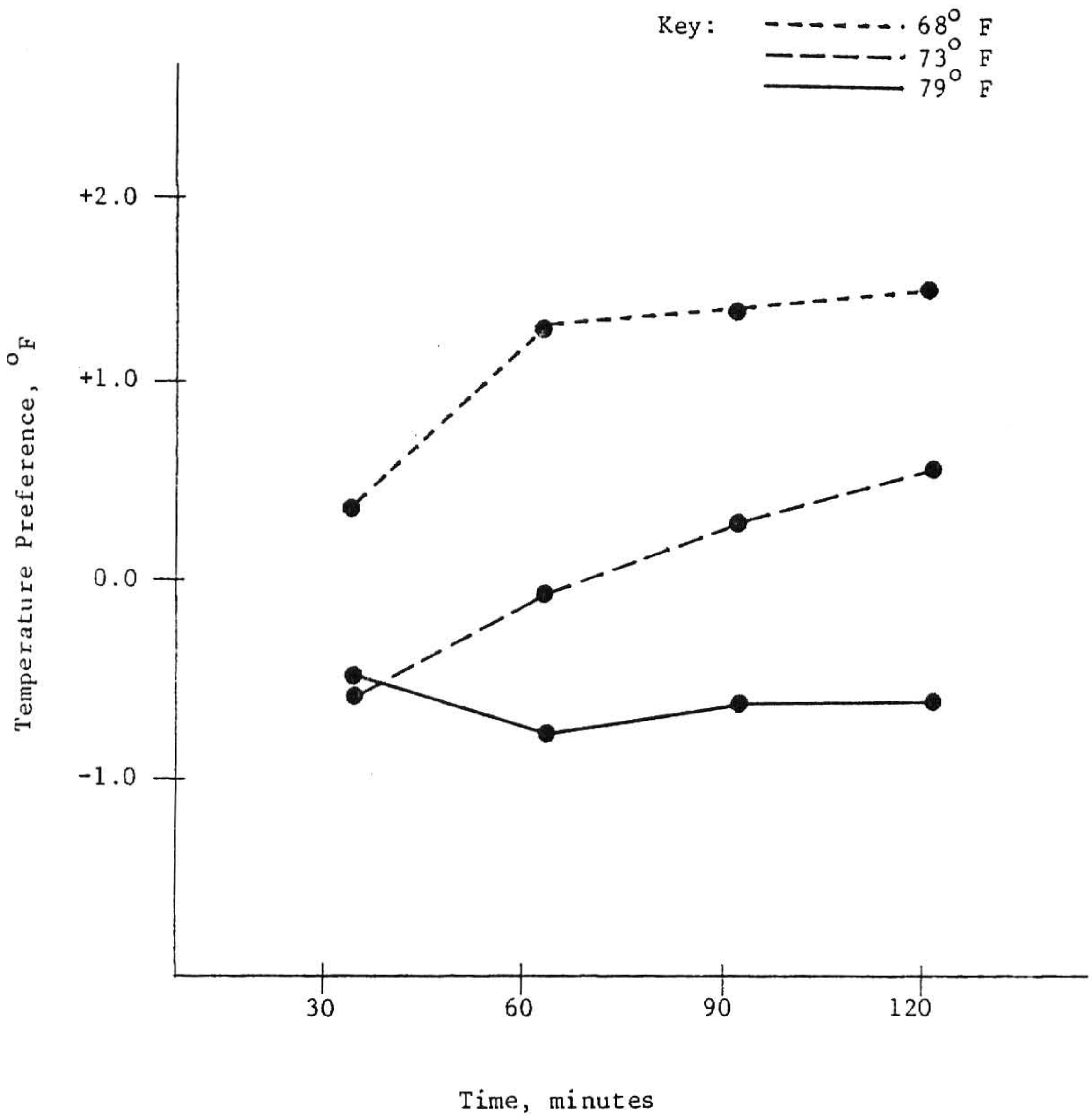

Figure 7: Temperature preference means over time at three environmental temperatures

Table 7: Separation of Means: Temperature Preference

A. Compare temperatures during the same time period:

LSD = 0.959 at 5%

30 MINUTES

68°F	79°F	73°F
0.438	-0.489	-0.542

60 MINUTES

68°F	73°F	79°F
1.375	-0.063	-0.745

90 MINUTES

68°F	73°F	79°F
1.479	0.375	-0.553

120 MINUTES

68°F	73°F	79°F
1.521	0.646	-0.553

B. Compare time passage at the same temperature:

LSD = 0.584 at 5%

68°F

30 minutes	60 minutes	90 minutes	120 minutes
0.438	1.375	1.479	1.521

73°F

30 minutes	60 minutes	90 minutes	120 minutes
-0.542	-0.063	0.375	0.646

79°F

30 minutes	90 minutes	120 minutes	60 minutes
-0.489	-0.553	-0.553	-0.745

Those means with common underlines are not significantly different at 5%.

warmer while after 60, 90, and 120 minutes they would have preferred a significantly higher temperature.

These findings are in agreement with the previous analysis of thermal sensation votes. As the votes become lower with time, the subjects are noted here as desiring a higher temperature for comfort.

The use of the temperature preference scale in conjunction with the thermal sensation scale and the thermal comfort scale is a relatively recent development (69). In the present study it has been used successfully in increasing the confidence with which this scale can be used in future research to build a stronger subjective measure of thermal response.

Summary of thermal response data

The thermal comfort rating, the thermal sensation score, and the temperature preference of the subjects compose the thermal response of the subjects in reaction to temperature, chair model, chair covering and the passage of time. Temperature was found to significantly affect thermal sensation. The subjects reacted differently at the three temperatures despite their differences in clothing insulation levels. At the lower temperature the subjects felt cooler than the subjects tested at the higher temperature. Chair model and chair covering had no effect on thermal comfort, thermal sensation, or temperature preference. Previous research by Rohles and Krohn (77) found the subjects in cloth covered chairs to have a higher thermal comfort level than those in vinyl covered chairs at 25.6°C (78°F). This study suggests that these differences do not appear at lower temperatures. The contradictory findings at high temperatures may be due to differences in methodology. The passage of time affected thermal sensation. During the testing, regardless of the other variable levels, the subjects changed their thermal sensation ratings from an initial neutral vote to a significantly cooler vote. This can be explained by the sedentary activity level of the subjects. The sensations however, were not extreme enough to affect thermal comfort.

The interaction of temperature by time was found to affect the temperature preference vote of the subjects. At lower temperatures, over time, the subjects preferred increasingly higher temperatures, again expected because of the length of time at a sedentary activity level.

Chair Attributes

The nonthermal perceptions of the chairs were analyzed with the use of the Chair Attribute Scale developed by Rohles and Krohn (77). It was developed in the same way and is in the same form as the thermal comfort scale (79): pairs of adjectives with nine possible rankings between them from one, the least desirable, to nine, the most desirable. The three factors of chair stylishness, chair size, and chair comfort were subjected to a weighting procedure to produce the following factors (77): Stylishness: unfashionable - fashionable, 0.87791; ugly - beautiful, 0.71613; unattractive - attractive, 0.88083; unstylish - stylish, 0.88741;

repelling - inviting, 0.85358; bad lines - good lines, 0.83948; unappealing - appealing, 0.87182; Size: small - large, 0.83063; cramped - roomy, 0.49176; tiny - huge, 0.89788; narrow - wide, 0.87290; Comfort: non-functional - functional, 0.83527; uncomfortable - comfortable, 0.75686; unpleasant - pleasant, 0.76584; poorly balanced - well balanced, 0.77623; inconvenient - convenient, 0.88178; and inefficient - efficient, 0.88853. Each scale was analyzed on a single value which was obtained by multiplying the subject's response by the factor for that pair and summing the responses. Chair style, chair size, and chair comfort as perceived by the subject were then subjected to separate analysis of variance using temperature, chair model, chair covering, and the passage of time as main sources of variance. Each perceived attribute is discussed separately.

Perceived stylishness of chairs

Significant differences in the perceived stylishness of the chairs were found at the interaction of chair model x chair covering x time. The analysis of the interaction is summarized in Tables 8 and 9 and in Figure 8. After 60 minutes the Manager chair model in both cloth and vinyl upholstery was judged significantly less stylish and the Concentric chair model in both the cloth and vinyl upholstery was judged significantly more stylish. After two hours the Manager chair model in cloth upholstery was judged to be significantly less stylish while the Concentric chair model in both vinyl and cloth upholstery and the Conference chair model

Table 8: Analysis of Variance of Perceived Stylishness

Source	df	SS	F-value	pr>F
Error (model)	117	1,270.41		
Error (Rep (Temperature))	15	4,592.60		
Temperature	2	1,550.86	2.53	0.1128
Error (Rep x Model x Cover (Temp))	104	18,633.94		
Model	3	2,288.64	4.26	0.0072
Cover	1	45.39	0.25	0.6158
Model x Cover	3	271.68	0.51	0.6834
Model x Temperature	6	1,630.33	1.52	0.1799
Temperature x Cover	2	381.74	1.07	0.3484
Model x Temperature x Cover	6	1,052.65	0.98	0.4432
Time	1	3.49	0.32	0.5717
Temperature x Time	2	0.00	0.00	1.0000
Model x Time	3	43.15	1.32	0.2689
Cover x Time	1	18.32	1.69	0.1965
Model x Temperature x Time	6	39.11	0.60	0.7296
Temperature x Cover x Time	2	22.13	1.02	0.3641
Model x Cover x Time	3	117.08	3.59	0.0157
Model x Temperature x Cover x Time	6	26.17	0.40	0.8767

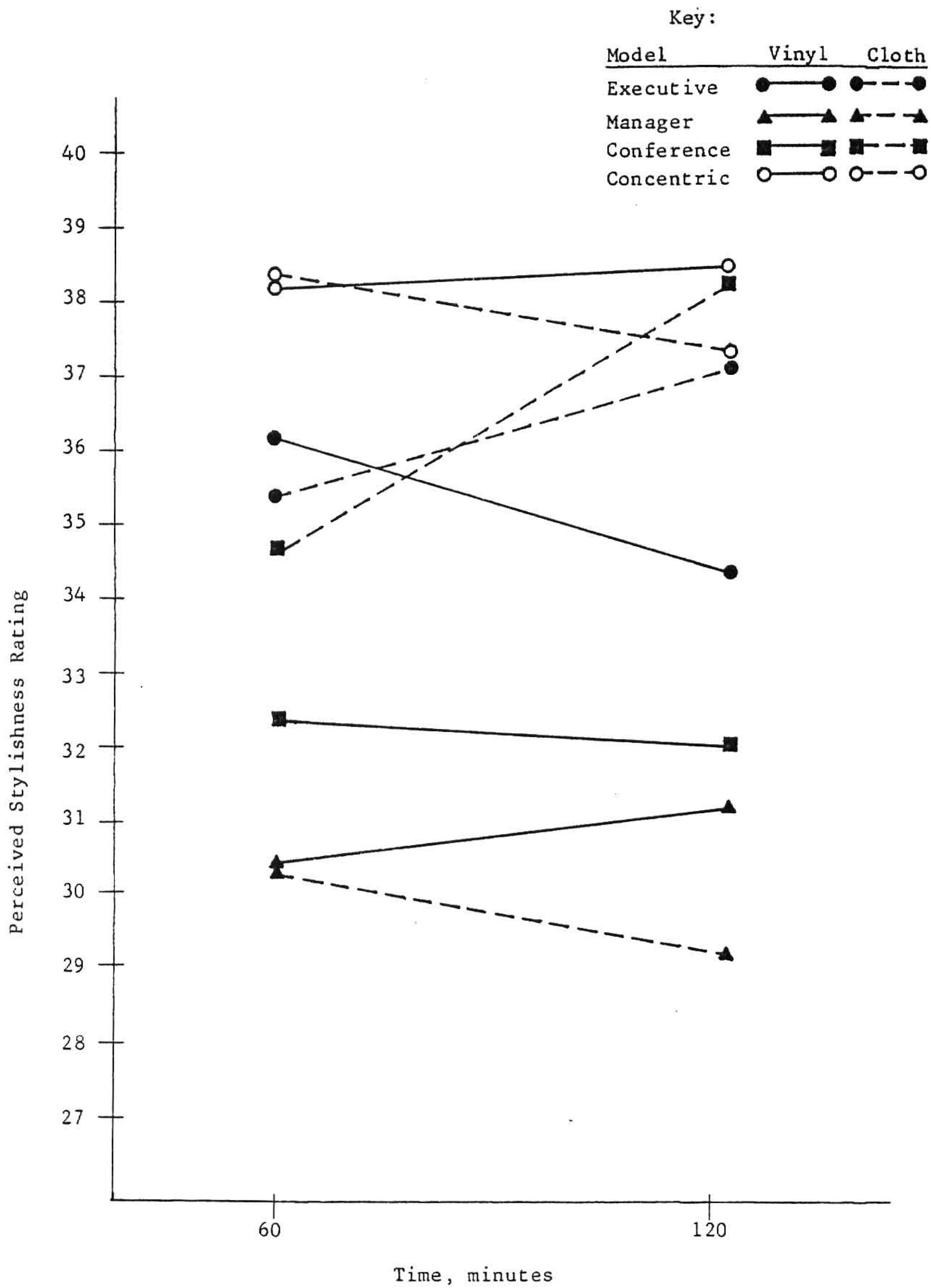

Figure 8: Stylishness means over time for four chair models covered in cloth and vinyl

Table 9: Separation of Means: Perceived Stylishness

A. Compare model x cover means at the same time period:

LSD = 5.158 at 5%

ONE HOUR

MAN-CL	MAN-VI	CNF-VI	CNF-CL	EXC-CL	EXC-VI	CNC-VI	CNC-CL
30.295	30.469	32.401	34.633	35.299	36.191	38.104	38.225

TWO HOURS

MAN-CL	MAN-VI	CNF-VI	EXC-VI	EXC-CL	CNC-CL	CNF-CL	CNC-VI
29.124	31.112	32.064	34.387	37.005	37.330	38.048	38.330

Those means with common underlines are not significantly different at 5%.

Table 9: Separation of Means: Perceived Stylishness

B. Compare time passage at the same model x cover:

LSD = 2.17 at 5%

Executive - Cloth		Executive - Vinyl	
1 hour	2 hours	1 hour	2 hours
35.299	37.005	36.191	34.387

Manager - Cloth		Manager - Vinyl	
1 hour	2 hours	1 hour	2 hours
30.295	29.124	30.469	31.112

Conference - Cloth		Conference - Vinyl	
1 hour	2 hours	1 hour	2 hours
34.633	38.048	32.401	32.064

Concentric - Cloth		Concentric - Vinyl	
1 hour	2 hours	1 hour	2 hours
38.225	37.330	38.104	38.330

Those means with common underlines are not significantly different at 5%.

in cloth upholstery were judged to be significantly more stylish. The Concentric chair is a newer model with more features than the other chairs. The Manager chair is very plain, although it does tilt and swivel and is on castors. All chairs were perceived similarly, as to stylishness, over time, except the Conference chair model in cloth. It was perceived as significantly more stylish after two hours than it was after one hour. This Conference chair in cloth was also found to be judged significantly more stylish than its counterpart in vinyl after two hours.

In previous research the Manager, the Executive, and the Conference chairs were judged as equally stylish when compared along with one other model which was judged to be less stylish than these three models (77). In this study the Concentric model was added and most likely affected the judgement of the subjects when its features were described.

Perceived Size of Chair

Significant effects were found at the three-way interaction level of chair model x temperature x chair cover. These effects are summarized in Tables 10 and 11 and in Figure 9.

Differences were found when the models in cloth and vinyl were compared at each temperature. At 20.0°C (68°F) the Concentric model in vinyl, the Manager model in cloth, and the Conference model in cloth were judged significantly smaller and the Manager model in vinyl and the Executive model in cloth were judged significantly larger. At 22.8°C (73°F), the vinyl covered models were

Table 10: Analysis of Variance of Perceived Size of Chairs

Source	df	SS	F-value	pr>F
Error (model)	117	354.22		
Error (Rep (Temperature))	15	733.48		
Temperature	2	39.07	0.40	0.6776
Error (Rep x Model x Cover (Temp))	104	2,147.96		
Model	3	305.56	4.93	0.0032
Cover	1	21.77	1.05	0.3069
Model x Cover	3	93.40	1.51	0.2157
Model x Temperature	6	159.19	1.26	0.2822
Temperature x Cover	2	241.72	5.85	0.0039
Model x Temperature x Cover	6	279.55	2.26	0.0436
Time	1	6.30	2.08	0.1519
Temperature x Time	2	1.99	0.33	0.7208
Model x Time	3	5.61	0.62	0.6089
Cover x Time	1	7.89	2.61	0.1092
Model x Temperature x Time	6	9.72	0.54	0.7804
Temperature x Cover x Time	2	7.51	1.24	0.2932
Model x Cover x Time	3	3.53	0.39	0.7646
Model x Temperature x Cover x Time	6	15.97	0.88	0.5128

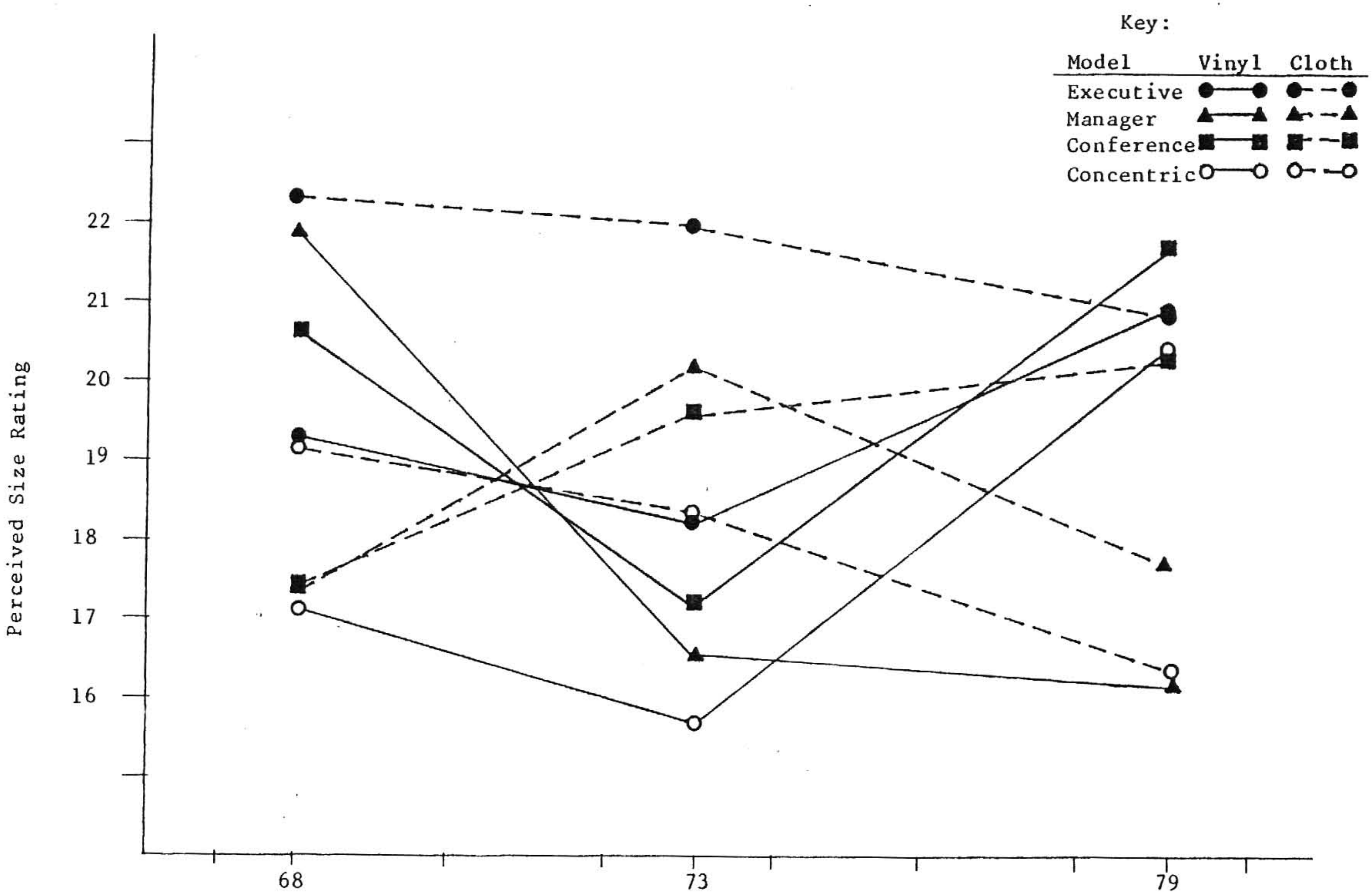

Figure 9: Size rating means of four chair models in cloth and vinyl coverings at three environmental temperatures.

Table 11: Separation of Means: Perceived Size of Chairs

A. Compare model x cover means at the same temperature:

LSD = 3.67 at 5%

68°F

CNC-VI	MAN-CL	CNF-CL	CNC-CL	EXC-VI	CNF-VI	MAN-VI	EXC-CL
17.17	17.42	17.51	18.52	18.54	20.61	21.97	22.16

73°F

CNC-VI	MAN-VI	CNF-VI	EXC-VI	CNC-CL	CNF-CL	MAN-CL	EXC-CL
15.74	16.49	17.17	18.14	18.32	19.63	20.18	21.92

79°F

MAN-VI	CNC-CL	MAN-CL	CNF-CL	CNC-VI	EXC-VI	EXC-CL	CNF-VI
16.18	16.24	17.75	20.25	20.33	20.85	20.86	21.74

Those means with common underlines are not significantly different at 5%.

Table 11: Separation of Means: Perceived Size of Chairs

B. Compare temperatures at the same model and cover

LSD = 5.021 at 5%

Executive - Cloth

79°F	73°F	68°F
20.86	21.92	22.16

Executive - Vinyl

73°F	68°F	79°F
18.14	18.54	20.85

Manager - Cloth

68°F	79°F	73°F
17.42	17.75	20.18

Manager - Vinyl

79°F	73°F	68°F
16.18	16.49	21.97

Conference - Cloth

68°F	73°F	79°F
17.51	19.63	20.25

Conference - Vinyl

73°F	68°F	79°F
17.17	20.61	21.74

Concentric - Cloth

79°F	73°F	68°F
16.24	18.32	18.52

Concentric - Vinyl

73°F	68°F	79°F
15.74	17.17	20.33

Those means with common underlines are not significantly different at 5%.

all judged to be smaller than the cloth covered models. When comparing the same model, the Manager and the Executive models show the vinyl-covered model to be judged significantly smaller than the cloth-covered model. At 26.1°C (79°F), the Manager model covered in vinyl and the Concentric model covered in cloth were judged to be relatively smaller. The Conference model covered in cloth and vinyl, the Executive model covered in cloth and vinyl, and the Concentric model covered in vinyl were judged significantly larger than the remaining three models.

When each model is examined at the three temperatures, the only significant difference appears in the Manager model covered in vinyl. At 20.0°C (68°F) it was judged to be significantly larger than it was judged to be at 22.8°C (73°F) and 26.1°C (79°F).

In previous research, Rohles and Krohn found the Executive model to be judged larger than the other models (77). Although the Executive model was judged to be amoung the larger chairs, it was not consistently judged the largest. The perceptions of the sizes of these chairs at the three temperatures is difficult to generalize.

Perceived Comfort of Chairs

Significant differences appeared at the interaction chair model x chair cover x time. After one hour the Executive chair model in vinyl was judged to be significantly less comfortable while the Concentric chair model in cloth and the Conference chair model in vinyl were perceived to be of higher comfort. After two hours the

Executive model covered in vinyl was again judged to be of low comfort but the Concentric model covered in vinyl was judged as a relatively comfortable chair. Over time all of the chair models were judged equally comfortable except that the Conference model covered in vinyl was judged significantly less comfortable after two hours than it had been judged after one hour.

In comparing the same style in vinyl and cloth at each time period the Executive model in vinyl was found to be significantly less comfortable than the Executive model in cloth, suggesting that the type of covering is more important to the subject's comfort with larger, more enveloping, chairs.

In previous research (77), the Executive, the Manager, and the Conference models were found to be of equal perceived comfort when compared with one other model. The addition of the Concentric model and the use of women as subjects, for whom the Executive chair may have seemed too cumbersome, may account for the difference in results found here. In the Rohles and Krohn study the women perceived all of the chairs to be larger than the men perceived them to be (77).

The analysis of perceived chair comfort is summarized in Tables 12 and 13 and in Figure 10.

Table 12: Analysis of Variance of Perceived Chair Comfort

Source	df	SS	F-value	pr>F
Error (model)	117	1,308.30		
Error (Rep (Temperature))	15	1,927.42		
Temperature	2	296.30	1.15	0.3421
Error (Rep x Model x Cover (Temperature))	104	13,149.49		
Model	3	828.96	2.19	0.0927
Cover	1	21.46	0.17	0.6812
Model x Cover	3	371.15	0.98	0.4073
Model x Temperature	6	366.68	0.48	0.8195
Temperature x Cover	2	100.37	0.40	0.6734
Model x Temperature x Cover	6	1,163.10	1.53	0.1746
Time	1	78.74	7.04	0.0091
Temperature x Time	2	6.74	0.30	0.7404
Model x Time	3	34.90	1.04	0.3783
Cover x Time	1	0.95	0.09	0.7703
Model x Temperature x Time	6	32.12	0.48	0.8230
Temperature x Cover x Time	2	18.88	0.84	0.4326
Model x Cover x Time	3	98.05	2.92	0.0363
Model x Temperature x Cover x Time	6	63.52	0.95	0.4646

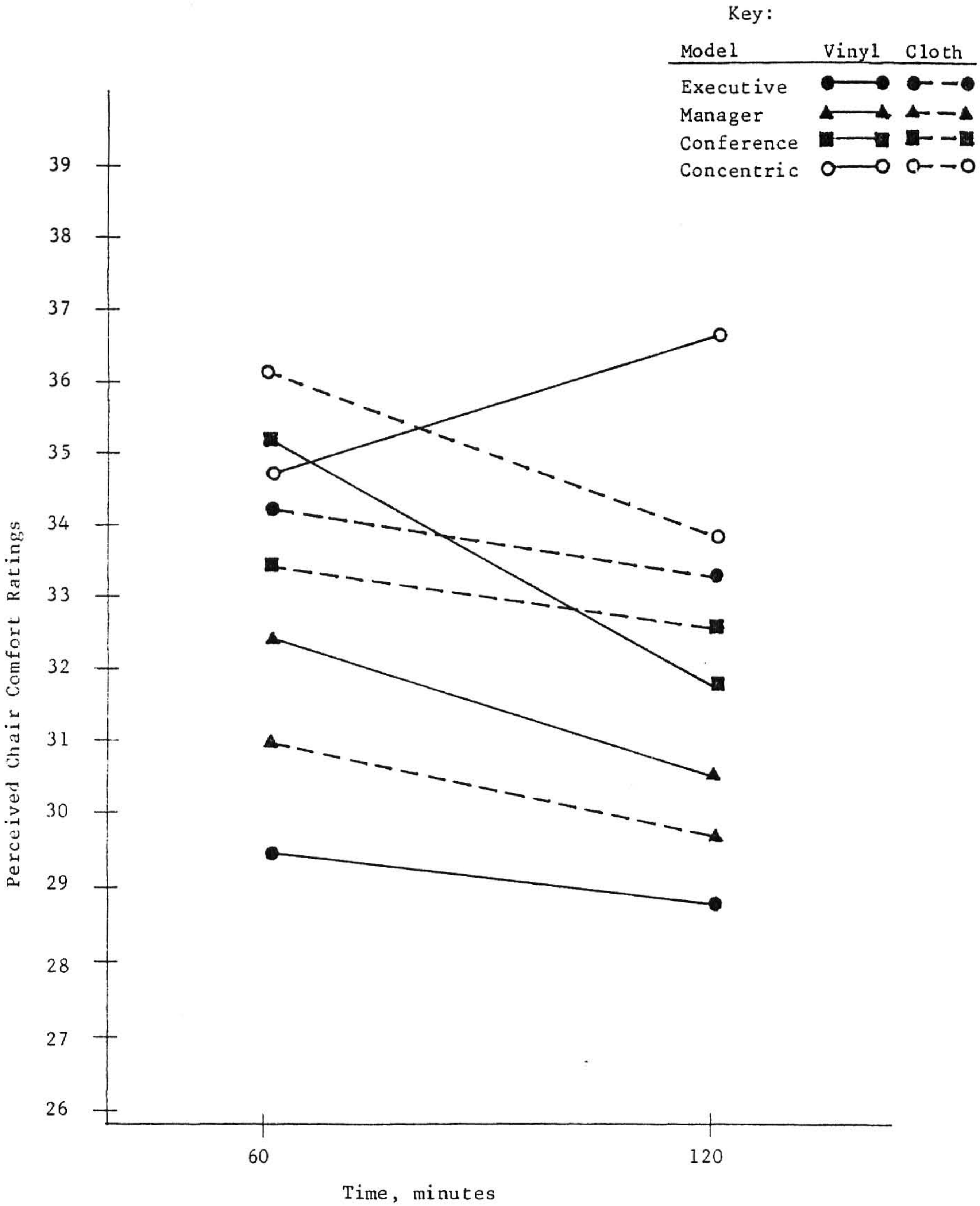

Figure 10: Comfort rating means of four chair models covered in cloth and vinyl upholstery after one and two hours

Table 13: Separation of Means: Perceived Chair Comfort

A. Compare model x cover means at the same time period:

LSD = 4.174 at 5%

ONE HOUR

EXC-VI	MAN-CL	MAN-VI	CNF-CL	EXC-CL	CNC-VI	CNF-VI	CNC-CL
29.579	31.006	32.560	33.489	34.118	34.745	35.219	36.026

TWO HOURS

EXC-VI	MAN-CL	MAN-VI	CNF-VI	CNF-CL	EXC-CL	CNC-CL	CNC-VI
28.978	29.928	30.682	31.958	32.749	33.334	33.969	36.605

Those means with common underlines are not significantly different at 5%.

Table 13: Separation of means: Perceived Chair Comfort

B. Compare time passage of each model x cover:

LSD = 2.207 at 5%

Executive - Cloth

1 hour	2 hours
34.118	33.334

Executive - Vinyl

1 hour	2 hours
29.579	28.978

Manager - Cloth

1 hour	2 hours
31.006	29.928

Manager - Vinyl

1 hour	2 hours
32.560	30.682

Conference - Cloth

1 hour	2 hours
33.489	32.749

Conference - Vinyl

1 hour	2 hours
35.219	31.958

Concentric - Cloth

1 hour	2 hours
36.026	33.969

Concentric - Vinyl

1 hour	2 hours
34.745	36.605

Those means with common underlines are not significantly different at 5%

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

This research was conducted to examine what effects temperature, chair model, chair covering, and time passage had on thermal response, as measured with subjective scaling procedures. In addition, the effects of these variables on the nonthermal attributes of four chair models were investigated. Four subjective scales, to measure subject thermal and nonthermal responses, were administered during a succession of two-hour long test sessions.

Conclusions

Thermal response was analyzed separately for the subjective ratings of thermal comfort, thermal sensation, and temperature preference. No significant differences at 0.05 were found for thermal comfort score, probably because the subjects wore the clothing insulation recommended for comfort at the temperatures used, which were within ASHRAE's applicable comfort zones. Neither chair model nor chair covering affected the subject's thermal comfort vote. This is contrary to the findings of Rohles and Krohn in similar research (77). They found that thermal comfort was greater in cloth covered chairs than in vinyl covered chairs. The differing results could be due to the number and gender of subjects, to slightly different levels of clothing insulation, or to different loadings used in the weighting procedure.

Thermal sensation vote was found to be affected by the main effects of temperature and time. At the higher temperature the subjects judged themselves to be warmer than the subjects at the lower temperature did, even with the change in the amount of clothing worn, in all of the chair models and chair coverings. The subjects sensed the warmness or coolness in their environment, but the sensation was apparently not extreme enough to cause them to be uncomfortable as seen in the stable thermal comfort scores. All thermal sensation means fell between 4 and 6, with 5 being neutral, which is consistent with ASHRAE's acceptable comfort zone (2). Over time, regardless of the other variable levels, the subjects felt cooler after an initially neutral vote.

Temperature preference showed how much warmer or cooler the subject would desire the temperature to be if she had the power to change the thermostat. An interaction between time and temperature was found to affect this variable. After two hours at 26.1°C (79°F) ET* a lower temperature was preferred, while during the first hour and a half at 20.0°C (68°F) ET* a higher temperature was preferred. After spending time at a given temperature, those at 26.1°C (79°F) ET* consistently desired the temperature to be lowered about 0.6°F. At 22.8°C (73°F) ET* a lower temperature was preferred during the first hour while a higher temperature was desired during the second hour. At 20.0°C (68°F) ET* initially a warmer temperature was desired and after one hour the temperature change desired was significantly higher than that after 30 minutes. These findings are consistent with the lowering of thermal sensation vote found over time. The use of the Temperature Preference Scale here helps to validate its use in making the subjective thermal response a stronger indicator. It is used along with the Thermal Sensation Scale and the Thermal Comfort Scale to fully describe subjective thermal response.

Low temperatures had a greater effect on subjective thermal sensation and temperature preference than did high temperatures as seen in the larger magnitude of difference of thermal sensation means from a neutral vote and the higher preferred temperatures at 20.0^{o}C (68^{o}F) ET*, even with the addition of a sweater to increase the clothing insulation to that 0.11 clo higher than that recommended by ASHRAE (2). So this study suggests that although designers continue to attempt to produce chairs that are comfortable, people's thermal response may be more affected by low winter temperatures and by spending long periods of time sitting than by the chair model or chair covering.

Chair Attributes

The chair attributes were analyzed separately for the subjective judgements of chair stylishness, chair size, and chair comfort. It was found that the interaction of chair model x chair cover x time was significant for both perceived chair stylishness and chair comfort. Initially the Manager model in cloth and vinyl was judged less stylish and the Concentric model in cloth and vinyl was judged to be more stylish. After two hours the Manager model covered in cloth was still judged to be less stylish and the two Concentric models were judged to be more stylish, but in addition the Conference model covered in cloth upholstery was also judged to be more stylish. The only time effect was revealed in the Conference model in cloth which was judged more stylish after two hours than it had been after one hour.

This interaction, chair model x chair cover x time, also appeared significant when analyzing the perceived chair comfort ratings. After both one hour and two hours the Executive model covered in vinyl was judged to be of lower comfort. After one hour the Concentric model covered in cloth upholstery and the Conference model covered in vinyl upholstery were judged to be of higher comfort. After two hours the Concentric model covered in vinyl upholstery was judged to be a more highly comfortable chair. When comparing cloth and vinyl upholstery on the same chair models it was found that the Executive model in vinyl upholstery was judged to be significantly less comfortable than the Executive model in cloth upholstery at all time periods. The Executive model was the largest and most enclosing of the models tested, suggesting that vinyl and cloth coverings are both acceptable if the chair is small, open, and with smaller upholstered areas, but that when the chair is large and enveloping, cloth upholstery is preferred over vinyl upholstery for comfort. When analyzed over time, the Conference model in vinyl was judged less comfortable after two hours than it had been after one hour.

Perceived chair size was found to be affected by chair model, temperature, and chair covering in a complicated interaction.

When combining these attribute ratings the most popular chairs were found to be the Concentric chair in cloth and vinyl upholstery, the Executive model in cloth upholstery, and the Conference model in cloth upholstery. The cloth covering was preferred, but vinyl was acceptable if the chair had other positive features. Experts and researchers, such as Stellman (50), Garrow and Wooler (25), and Grandjean (30) have recommended cloth covering as inherently more comfortable. The present study also concludes that cloth covering is preferred over vinyl covering.

Recommendations

1. The Concentric chair model in cloth or vinyl upholstery, the Executive model in cloth upholstery and the Conference model in cloth upholstery would be good choices for women who must spend long periods of time sitting. The many adjustable features on the Concentric model seemed to make it more acceptable in either the cloth or vinyl covering.

2. When choosing chairs to place in areas that would experience the three temperatures here tested, the specifier need not be overly concerned about the effect of upholstery. Cloth and vinyl coverings affected the subjects similarly at all three temperatures.

3. Further research could be conducted on males in a similar manner as that described here to find if there are any sex differences in the results.

4. Further research could be conducted at higher temperatures, to simulate extreme un-airconditioned environments, to assess whether chair covering then affects thermal comfort.

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APPENDIX

VOLUNTEERS NEEDED

180 WOMEN volunteers are needed for an environmental research study from March 21 through April 11, 1983. Participation will include about 2½ hours of your time on one occasion for which you will receive 2 hours of experimentation credit. During the first 30 minutes, you will dress in a clothing ensemble provided for you. In the following two hours you will be seated in a test room where you will be able to study or read.

If you would like to participate, come to the Institute for Environmental Research office in Seaton Hall, Monday - Friday from 9:30 - 11:45 or 12:30 - 4:30 to sign up.

Notice: PLEASE DON'T SIGN UP FOR THIS STUDY UNLESS YOU WILL COME TO THE TESTING SESSION. IT IS IMPERATIVE TO THE EXPERIMENT THAT YOU ARE PROMPT AND KEEP YOUR TESTING APPOINTMENT!!!

If you have any questions, please call Kristi Anderson at 539-8134 or Dr. Deanna Munson at 532-6993.

Participation in this experiment fulfills 2 hours of experimental credit.

Recruitment Orientation Statement

The purpose of this study is to determine how people respond to their thermal environment. You should be fully aware that the conditions to which you will be exposed entail no physical risks. Second, you have volunteered to act as a subject and are participating on your own volition. Third, you may stop participating in the experiment if necessary. Fourth, your identity as a subject will not be disclosed and anonymity will be maintained.

Your participation will include 2½ hours of your time on one occasion. During the first 30 minutes, you will dress in a clothing ensemble that will be provided for you. In the following two hours, you will be seated in a test room, where you will be able to study or read. You can bring reading materials with you, although some will be provided. You may not sleep, walk about, or leave the room during the tests. At certain intervals you will be asked to complete ballots evaluating the temperature of the environment and your comfort. You will be given 2 hours of experimentation credit for your participation.

If you decide to participate, fill out an information form which will be given to you by Institute personnel. Then sign up for a date and time when you can participate.

Subject Information Form

Please fill out this form and give it to the person in charge of registration. It is important that you give us complete and accurate information so that we may contact you before your test appointment and assign you a clothing ensemble that will fit.

Test Number________________________(filled out by researcher)

Subject Number ____________________(filled out by researcher)

Name ____

Address (current) ____

Telephone (current) ______________________________________

Garment sizing information:

Height __________________

Weight __________________

Shirt size _______________ Misses

Slack size _______________ Misses

Blazer size ______________ Misses

If you have any questions or need help in sizing, please ask the person in charge of registration.

Thank you for your cooperation.

To be filled in by researcher:

Shirt _______________ Pant _______________ Blazer _______________

Assignment Slip

Thank you for volunteering to participate in this study. You are scheduled to report to the Institute for Environmental Research for testing on the following day and time:

______________________________, 1983 at ____________________________

You will be tested in an environment maintained at either a slightly cool, a neutral, or a slightly warm temperature. You will be wearing an appropriate clothing ensemble which will be given to you at the time of the test. You are to wear your own tennis or track shoes and underwear with the ensemble. It is important that you do not consume alcohol or drugs within 24 hours prior to the time you are scheduled for testing. You should plan to bring study or reading materials for the two hour test.

IT IS IMPERATIVE THAT YOU ARE PROMPT FOR YOUR SCHEDULED TEST APPOINTMENT ! ! !

AGREEMENT AND RELEASE

1. I, ______________________________ vounteer to participate in a project in connection with research studies to be conducted by Kansas State University.

2. I fully understand the purpose of the study as outlined in the orientation statement and test protocol.

3. I understand that I may be observed during my participation and that my conduct and/or voice may be recorded by photographic and/or recording devices. I also relize that public reports and articles may be made of the experiments and all of the observations, and I consent to publication of such including the use of photographs if by face is "blanked" out.

4. I understand also that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring anonymity of my performance and response.

5. I understand that I will be permitted to leave the test at any time and I may discontinue participation without penalty or loss of benefits to which I am otherwise entitled.

6. As compensation for my voluntary services as a participant in the aforesaid studies, Kansas State University may pay me. It is clearly understood and agreed, however, that in no event am I to be considered an employee of Kansas State University during such participation. Therefore, no Social Security, income tax, retirement or other benefirs of employment will be deducted or accrued.

7. I hereby agree, under penalty of forfeiture of all compensation due me, not to give information regarding these studies to any public news media nor to publicize any articles or other accounts thereof without prior written approval of Kansas State University.

8. If I have any questions concerning my rights as a test subject, injuries or emergencies resulting from my participation or any questions concerning the study, I understand that I can contact Kristi Anderson at 539-8134 (evenings), 532-6993 (days).

I have read the Subject Orientation and explanation of the Test Protocol statement and signed the herein Agreement and Release, this ____________ day of ______________________, 19___.

____

Signature

Instuctions to the subjects:

On the thermal comfort computer card and on the chair attribute scale are several pairs of adjectives that can be used to describe how the environment in this room, or the chair in which you are seated, feels to you. Look over the list of adjectives, then take a few minutes to get into the mood of the situation and then complete the ratings according to the following instructions:

If you feel that the environment can be described <u>very closely</u> by the adjective at <u>one end</u> of the scale you should place your checkmark as follows:

fair √,__,__,__,__,__,__,__,__ unfair
fair __,__,__,__,__,__,__,__,√ unfair

If you feel that the environment can be described <u>quite closely</u> by the adjective at one or the other end of the scale (but not extremely) you should place your checkmark as follow:

strong __,√,__,__,__,__,__,__,__ weak
strong __,__,__,__,__,__,__,√,__ weak

If you feel that the environment can be described <u>somewhat closely</u> by the adjective at one or the other end of the scale you should make your checkmark as follows:

near __,__,√,__,__,__,__,__,__ far
near __,__,__,__,__,__,√,__,__ far

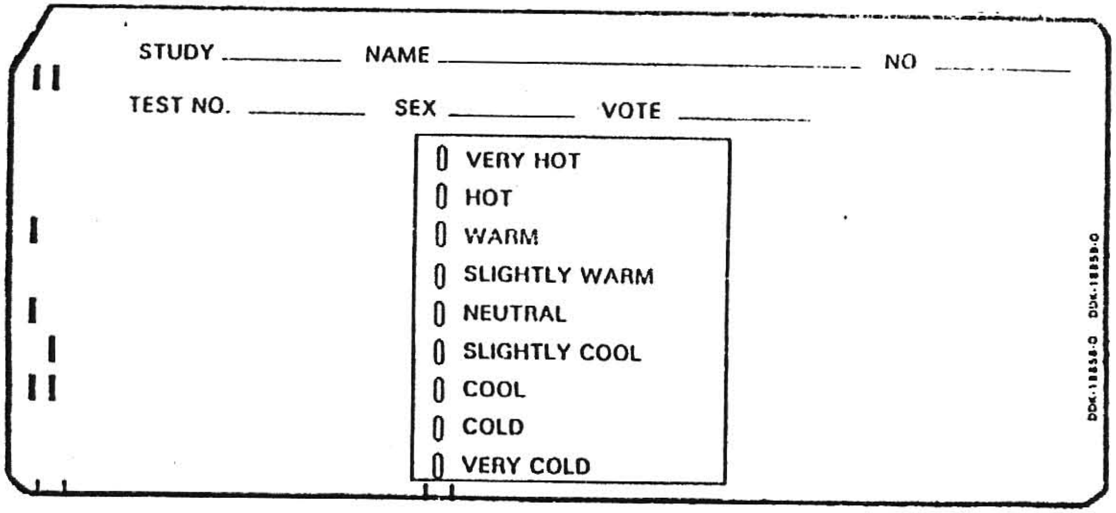
If you feel that the environment can be described <u>only slightly</u> by the adjective at one or the other end of the scale you should make your checkmark as follows:

active __,__,__,√,__,__,__,__,__ passive
active __,__,__,__,__,√,__,__,__ passive

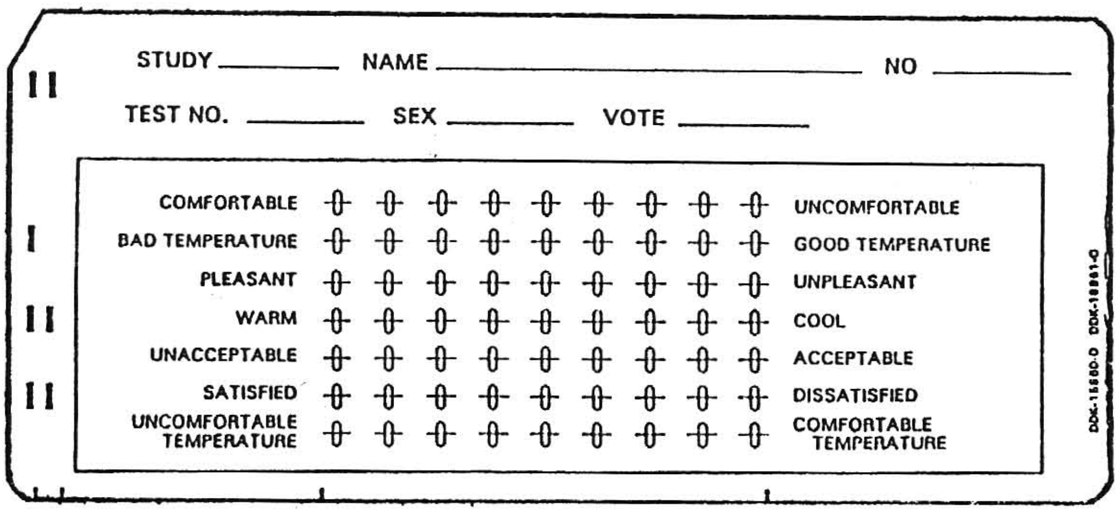
If you feel that the environment can be described as <u>neutral</u>, or if the scale is <u>completely irrelevent</u> or unrelated to the environment, then you should place the checkmark as follows:

safe __,__,__,__,√,__,__,__,__ dangerous

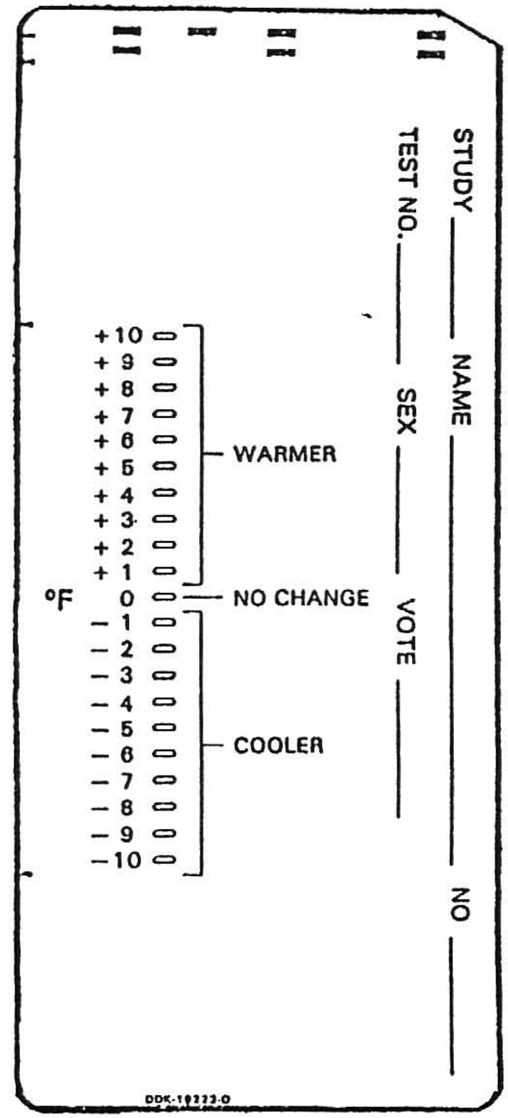
PLEASE: 1) Place your checkmark <u>in the middle of the spaces</u>.
2) <u>Do not omit any</u>.
3) Do not put more than one checkmark to a question.



Thermal Sensation



Thermal Comfort



Temperature Preference

Computer Card Ballots

THE EFFECT OF CHAIR STYLE
AND COVERING
ON THERMAL COMFORT

BY

KRISTI ANDERSON-SUNDLIE

B.A., Concordia College, 1981

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1983

ABSTRACT

This two-part study examined the effect of chair style and covering, temperature, and time passage on thermal response and on perceived chair attributes. A 4 x 2 x 3 x 4 factorial design, with repeated measures with respect to time, was used to study the main effects and interactions of four independent variables: 1) chair model at four levels: Executive Model, Manager Model, Conference Model, and Concentric Model; 2) chair upholstery at two levels: cloth and vinyl; 3) temperature at three levels: 20.0°C (68°F) ET*, 22.8°C (73°F) ET*, and 26.1°C (79°F) ET*; and 4) time at four levels: ½ hour, 1 hour, 1½ hour, and 2 hours. Two dependent variables, thermal response and chair attributes, were studied. Thermal response was measured with three scales: Thermal Comfort Score, Thermal Sensation, and Temperature Preference. The chair attributes - stylishness, size, and comfort - were measured with the Chair Attribute Scale. The study was carried out in two-hour sessions in the Institute for Environmental Research's environmentally controlled chamber. Clothing ensembles were furnished for the subjects, recruited from the student body of Kansas State University. Each set of variables was replicated six times for a total of 143 sets of data.

Analysis of variance and Fisher's Least Significant Difference Test were used to find significant main effects and interactions of the variables. Results showed that thermal response was affected by temperature, time, and the interaction temperature and time. Thermal Comfort Score was not affected. Thermal Sensation Scores showed subjects

to be cooler at 20.0°C (68°F) and warmer at 26.1°C (79°F). Over time, thermal sensation decreased. Temperature Preference remained stable at 26.1°C (79°F). At 22.8°C (73°F) the subjects initially preferred a lower temperature, but after 90 minutes preferred a higher temperature. At 20.0°C (68°F) the subjects initially were quite satisfied with the temperature, but after one hour preferred a higher temperature.

Analysis of the chair attributes showed that perceived stylishness and perceived comfort were affected by chair model, chair covering, and time passage. Perceived chair size was affected by chair model, chair covering, and temperature. Based on the results, the Concentric Model, cloth and vinyl covered, with its adjustable features, was rated among the most comfortable and stylish. The Executive Model and the Conference Model, both in cloth, were also rated highly in these two areas. The perceived size ratings of these models, however, varied with temperature.