Identification of the Most Significant Properties Influencing Tactile Fabric Comfort Using Regression Analysis

LES M. SZTANDERA
Computer Information Systems
Philadelphia University
School House Lane and Henry Avenues
Philadelphia, Pennsylvania 19144-5497
UNITED STATES OF AMERICA
sztanderal@philau.edu http://www.philau.edu

Abstract: - Engineered fabrics are being used increasingly in commercial and domain-specific systems. Such fabrics with specified consumer-desired characteristics can be computationally designed. Through the use of an extensive database that correlates sensory and mechanical properties with tactile comfort assessments, desired comfort can be predicted by measuring a limited number of properties. In this paper we are focusing on the most significant sensory and mechanical properties influencing tactile fabric comfort. Output systems can be optimized to exhibit the highest level of comfort by engineering a fabric with specific sensory and mechanical properties. This paper examines stepwise regression analysis and identifies the most significant properties influencing tactile fabric comfort. The reported Beta coefficients are the standardized regression coefficients. Their absolute magnitudes reflect their relative importance in predicting comfort values. A universe of 48 fabrics is examined to analyze and map the relations. The initial 17 mechanical and 17 sensory parameter sets are reduced to sets of 1 to 4 and 1 to 5 properties, respectively. Adjusted R^2 values were 0.360 to 0.657 for mechanical and 0.713 to 0.863 for sensory parameters, reflecting sound goodness-of-fit measures, and providing reasonable ways for identifying the mechanical and sensory properties that are most significant influences on tactile fabric comfort. Elongation and hysteresis of shear force were found to be the most influential mechanical properties, while compression resilience rate and graininess were found to be the sensory properties that most impacted comfort.

Key-Words: tactile perception, fabric mechanical properties, stepwise regression analysis, standardized importance factors, textile property analysis

1 Introduction

To introduce a reader to the scope of the problem, we review the tactile perception and influencing factors here, previously reported in [1]. Numerous previous attempts have been made to correlate fabric properties with perceived comfort. Many methods have been used to build models for prediction of tactile comfort. Analyzing the relationship between quantifiable characteristics of fabrics in the context of predicting the tactile perception has been researched because of the increased application of sophisticated fabrics for functional clothing systems. Engineered fabrics are being used increasingly in commercial and domain-specific systems. Such fabrics with specified desirable consumer characteristics can be computationally designed.

Previously developed models based on energy equations [2], finite element analysis [3,4], stochastic formulations [5], and Artificial Neural Networks [6] exist to identify the interrelationship between the structure of textile materials and their functional properties. Linear models to predict the tactile comfort of textile materials in terms of both subjective and objective measurements are also found [7]. Researchers have found that human tactile perception of a textile material is complex [8], thereby limiting the application of the existing models. Moreover, these models are domain-specific and their extent of extrapolation is limited. In this paper, which describes research that followed the research reported in [1], standardized importance factors are used to identify the most significant sensory and mechanical factors influencing perceived tactile fabric comfort.

2 Data Collection – Mechanical, Sensory Properties, and Tactile Comfort Measurements

As reported in [1], a diversified set of 48 fabrics (universe of fabrics), including woven, knitted, and nonwoven materials, was selected for evaluation. Laminated fabrics with water-, fire-, and chemical-retardant finishes were included. The fabrics' mechanical properties, measured using the KES-FB Kawabata Evaluation System, are in Table 1. While these 17 properties form the independent variables, a human perception score of tactile comfort is used as a dependent variable. The human perception score is measured using the Comfort Affective Labelled Magnitude (CALM) scale, shown in Figure 1. The scale, developed at the Individual Protection Directorate, US Army Natick Soldier Center, Natick, MA, ranges from –100 to 100, where a score of –100 represents the greatest imaginable discomfort, and a 100 represents the greatest imaginable comfort. The other labels are distributed in a progressive ratio scale [9].

We repeat here the process of the developing the scale, after [9], as it completely defines the way our output variable, tactile fabric comfort, was formed. According to the scale developers [9] in order to develop a sensitive, reliable, and valid labeled magnitude scale of comfort, thirty-five volunteers, none of whom were members of the descriptive hand panel, were recruited from a random list. Word adjectives that could be used to modify the terms "comfortable" and "uncomfortable" to reflect intensity differences were compiled from previous scaling literature and from standard English language resources. The adjectives "greatest imaginable" and "greatest possible" were included to define scale values commensurate with a common fixed end-point of positive and negative affective experience, as used in previously developed labeled magnitude scales [9]. These adjectives were used to create forty-one word phrases, which in combination with two nonpolar terms ("neutral" and "neither comfortable nor uncomfortable"), resulted in a total of forty-three phrases to be used in scale development. The forty-three phrases were printed on separate pages and assembled in random order into testing booklets. Before testing, subjects were provided with written instructions on the procedure to be used in scaling the semantic meaning of the phrases. Oral instructions with an example were also provided. Subjects sequentially rated each of the phrases to index the magnitude of comfort or discomfort connoted by the phrase, using a modulus-free magnitude estimation procedure. In this procedure, subjects assign an arbitrary number to indicate the magnitude of comfort or discomfort reflected by the first phrase (positive numbers used for comfort, negative numbers for discomfort). Subjects then make all subsequent judgments relative to the first, so that if the second phrase denotes twice as much comfort as the first, a number twice as large is assigned; if it denotes one third as much comfort, a number one-third as large as the first is assigned, etc. All ratings were made in spaces provided in the testing booklet [9].

A subset of phrases was chosen to construct a labeled magnitude scale of comfort [9]. The criteria for selecting terms were low variability in perceived semantic meaning, parallelism in the terms used to describe comfort and discomfort, and selection of an equal number of comfortable and uncomfortable phrases (a decision based on evidence from the preference scaling literature showing that balanced scales are better for differentiating products).

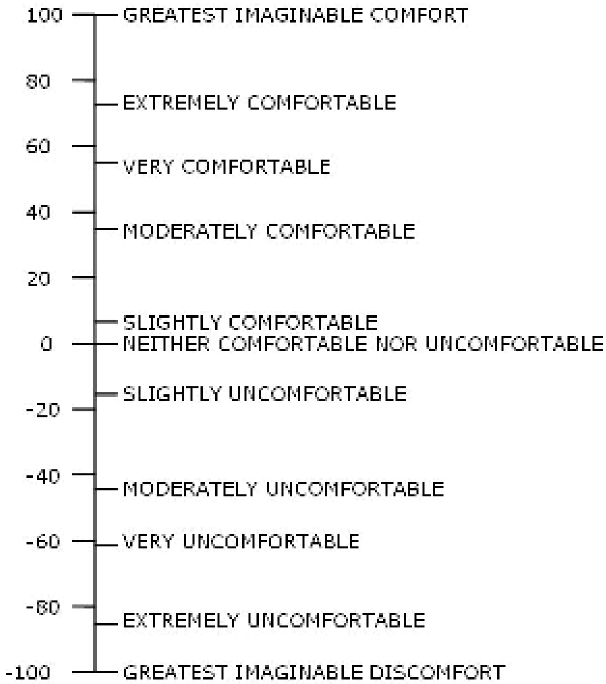
Examination of the standard errors of the geometric means for each of the phrases [9] led to the elimination of several phrases (e.g., "mediocre comfort," "barely comfortable," "a little comfortable") due to their variable semantic meaning to the subjects. Other phrases were eliminated because of a lack of suitable parallelism in terminology for the purpose of establishing bipolarity (e.g., "superior comfort," "oppressively uncomfortable"). Applying the remaining criterion to the phrases resulted in the selection of eleven phrases for use in the scale: five associated with comfort, five associated with discomfort, and one neutral term ("neither comfortable nor uncomfortable") to define the zero point. The geometric mean magnitude estimates of the positive and negative phrases were transformed to range from 0 to +100 (positive phrases) and 0 to -100 (negative phrases). The phrases were then placed along a 100-mm vertical analogue line scale in accordance with their transformed values. The resulting labeled affective magnitude scale of comfort is shown in Figure 1.

The comfort affect labeled magnitude (CALM) scale shown in Figure 1 has several advantages over other comfort scales commonly used in the literature [9]. With this scale, the level of comfort or discomfort experienced by an individual can be readily indexed by simply placing a mark somewhere on the line. This stands in contrast to the difficulty often encountered by subjects using magnitude estimation procedures. However, by having positioned the phrases of comfort/discomfort along the analogue line scale at points representing the magnitude of their semantic meaning as determined by a magnitude estimation procedure, it becomes possible to treat the measured distances along the scale as ratio level data. This stands in contrast to category scales of comfort, which provide only ordinal data. The ratio nature of the CALM scale enables statements to be made about whether a particular sample is 20%, 40%, three times, etc., as comfortable (or uncomfortable) as another sample. In addition, it does not require that the data be normalized, as is the case with magnitude estimates. Last, by using the "greatest imaginable" comfort (or discomfort) as end-points on the scale, the scale enables better discrimination between samples/conditions that are either very high or very low in comfort/discomfort and establishes a common ruler by which comfort/discomfort ratings of different subjects can be compared.

Table 1
Range of Mechanical Properties as Measured Using KES-FB Kawabata Evaluation System

Property	Description	Minimum Value	Maximum Value
EMT	Elongation (%)	[illegible]	[illegible]
LT	Linearity of load-extension curve (LT)	[illegible]	[illegible]
WT	Tensile energy (gf.cm/cm²)	[illegible]	[illegible]
RT	Tensile resilience (%)	[illegible]	[illegible]
B	Bending rigidity (gf.cm²/cm)	[illegible]	[illegible]
2HB	Hysteresis of bending moment (gf.cm/cm)	[illegible]	[illegible]
G	Shear rigidity (gf/cm. degree)	[illegible]	[illegible]
2HG	Hysteresis of shear force at 0.5 degree of shear angle (gf/cm)	[illegible]	[illegible]
2HG5	Hysteresis of shear force at 5 degrees of shear angle (gf/cm)	[illegible]	[illegible]
LC	Linearity of compression thickness curve (LC)	0.23	[illegible]
WC	Compressional energy (gf.cm/cm²)	[illegible]	[illegible]
RC	Compressional resilience (%)	[illegible]	[illegible]
MIU	Coefficient of friction (MIU)	[illegible]	[illegible]
MMD	Mean deviation of MIU (MMD)	[illegible]	[illegible]
SMD	Geometrical roughness (micron)	[illegible]	[illegible]
T	Fabric thickness (mm)	[illegible]	[illegible]
W	Fabric weight per unit area (mg/cm²)	[illegible]	[illegible]

Figure 1
Comfort Affective Labelled Magnitude (CALM) Scale



The same set of fabrics was evaluated subjectively for seventeen sensory properties, and the sensory property ranges of those fabrics are listed in Table 2.

Table 2
Range of Sensory Properties

Property	Lower Boundary	Upper Boundary
Gritty	4.45	12.47
Grainy	2.27	12.28
Fuzzy (circular motion)	1.83	9.80
Thickness	2.75	14.41
Tensile Stretch	0.677	14.49
Hand Friction	4.28	12.04
Fabric to Fabric Friction	4.11	13.04
Depression Depth	1.56	12.15
Springiness	1.39	9.01
Force to Gather	1.78	14.78
Force to Compress	1.68	14.20
Fullness/ Volume	2.32	15.17
Stiffness	1.59	14.49
Compression Resilience	1.63	13.43
Compression Resilience Rate	1.56	13.64
Noise Intensity	1.48	13.20
Noise	2.52	13.28

As reported in [1], 48 fabric specimens were selected for evaluation of mechanical and sensory properties, and the same set of fabrics was evaluated by 50 human subjects for perceived tactile comfort CALM scores. The fabric samples were sequenced in random order for the subjects to evaluate.

The mechanical properties were tested with 5 replicates making a data set of 240 seventeen-dimensional vectors. The sensory properties were tested with 27 replicates resulting in a data set of 1,296 seventeen-dimensional vectors. The above-mentioned vectors (mechanical and sensory) were mapped to 2,400 tactile comfort scores (48x50). Averages were selected to represent the seventeen-dimensional vectors and their corresponding tactile comfort scores in both cases. Both sensory and Kawabata mechanical properties include seventeen independent attributes and one dependent attribute. Though all the independent attributes contribute in the regression equation to predict the tactile comfort score, a few of the attributes contribute more than others. If the attributes that contribute the least to the prediction ability of the regression equation are eliminated, the overall dimension of the data set comes down. One of the mechanisms to reduce the dimension of the data is stepwise regression analysis.

3 Methods

3.1. Stepwise Regression Analysis

Data containing the mechanical properties and the CALM score for 48 fabrics are used to formulate the set of stepwise (forward) regression equations 1 through 4. Out of the seventeen parameters, four were included in 4, the final equation, based on the parameters' contribution to the overall variance of the data set.

Similarly, a set of regression equations relating the sensory properties and the tactile comfort score is formulated using the set of attributes selected using the stepwise regression approach. The formed relations are given in equations 5 through 9. In 9, the final equation, five out of the seventeen sensory properties are included.

The attributes were entered or removed in the steps of forward regression analysis based on the significance (probability) of the F value, which shows the significance level associated with adding the variable for that step. The stepwise criteria used was (probability of F to enter <=0.05; probability of F to remove >=0.1).

Standardized coefficients (Beta) were also calculated. These are the coefficients that were obtained by standardizing all of the variables in the regression, including the dependent and all of the independent variables, and running the regression. By standardizing the variables before running the regression, all of the variables were put on the same scale, thus allowing for comparison of the magnitude of the coefficients to see which one has more of an effect. Beta coefficients can be compared only within a model, not between models. Because the non-standardized coefficients (B) deal with raw (or "original") values, they are used to construct the prediction equations from sensory and mechanical parameters to perceived comfort. The equations are given below as 1 through 9. All non-standardized (B) and standardized coefficients (Beta) are listed in Tables 3 and 4. The excluded mechanical and handfeel variables, for all models, are listed in Tables 5 and 6, respectively.

<u>Mechanical Properties vs. Comfort</u>

$$\textit{Tactile Comfort Score} = -11.228 + 2.458\ \textit{EMT} \tag{1}$$

The equation fits with the R^2 value of 0.374 and the adjusted R^2 of 0.360.

$$\textit{Tactile Comfort Score} = 0.785 + 1.922\ \textit{EMT} - 17.741\textit{B} \tag{2}$$

The equation fits with the R^2 value of 0.547 and the adjusted R^2 of 0.526.

$$\textit{Tactile Comfort Score} = 39.162 + 1.620\ \textit{EMT} - 14.837\ \textit{B} - 47.846\ \textit{LT} \tag{3}$$

The equation fits with the R^2 value of 0.619 and the adjusted R^2 of 0.592.

$$\textit{Tactile Comfort Score} = 48.626 + 1.292\ \textit{EMT} - 43.468\ \textit{B} - 52.352\ \textit{LT} + 0.992\ \textit{HG} \tag{4}$$

The equation fits with the R^2 value of 0.687 and the adjusted R^2 of 0.657.

<u>Sensory Properties vs. Comfort</u>

$$\textit{Tactile Comfort Score} = 79.803 - 11.188\ \textit{Compression Resilience} \tag{5}$$

The equation fits with the R^2 value of 0.719 and the adjusted R^2 of 0.713.

$$\textit{Tactile Comfort Score} = 93.112 - 9.022\ \textit{Compression Resilience} - 4.230\ \textit{Grainy} \tag{6}$$

The equation fits with the R^2 value of 0.786 and the adjusted R^2 of 0.776.

Tactile Comfort Score = 123.903 – 8.471 Compression Resilience – 4.001 Grainy – 4.030 Gritty (7)

The equation fits with the R^2 value of 0.832 and the adjusted R^2 of 0.821.

Tactile Comfort Score = 100.313 – 6.399 Compression Resilience – 4.282 Grainy – 3.626 Gritty + 1.984 Tensile Stretch (8)

The equation fits with the R^2 value of 0.863 and the adjusted R^2 of 0.850.

Tactile Comfort Score = 84.991 – 5.908 Compression Resilience – 4.140 Grainy – 3.917 Gritty + 1.763 Tensile Stretch + 3.171Fuzzy (9)

The equation fits with the R^2 value of 0.878 and the adjusted R^2 of 0.863.

The adjusted R^2 measures the proportion of the variation in the Tactile Comfort Score accounted for by the independent mechanical and sensory variables [1]. Unlike R^2, the adjusted R^2 allows for the degrees of freedom associated with the sums of the squares. Therefore, even though the residual sum of squares decreases or remains the same as new independent variables are added, the residual variance does not. For this reason, adjusted R^2 is generally considered to be a more accurate goodness-of-fit measure than R^2.

4 Conclusion

Through the use of an extensive database that correlates sensory and mechanical properties with tactile comfort assessments, desired comfort can be predicted by measuring a limited number of properties. Ultimately, an engineered fabric with specified consumer-desired characteristics can be computationally designed.

In this paper we have focused on the most significant sensory and mechanical properties influencing tactile fabric comfort, and have identified them. The initial 17 mechanical and 17 sensory parameter sets are reduced to sets of 1 to 4 and 1 to 5 properties, respectively. Adjusted R^2 values were 0.360 to 0.657 for mechanical and 0.713 to 0.863 for sensory parameters, reflecting sound goodness-of-fit measures, and providing reasonable ways for identifying the mechanical and sensory properties that are most significant influences on tactile fabric comfort. Elongation and hysteresis of shear force were found to be the most influential mechanical properties, while compression resilience rate and graininess were found to be the sensory properties that most impacted comfort.

It is expected that an Artificial Neural Network approach [10, 11] will capture more complex relationships among the properties and the corresponding tactile comfort scores, and will result in higher adjusted R^2 values.

Table 3
Coefficients for Mechanical Properties

Equation		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta
1	(Constant)	–11.228	5.141	
	K_EMT	2.458	.474	.612
2	(Constant)	.785	5.306	
	K_EMT	1.922	.428	.478
	K_B	–17.741	4.329	–.437
3	(Constant)	39.162	14.378	
	K_EMT	1.620	.411	.403
	K_B	–14.837	4.146	–.365
	K_LT	–47.846	16.841	–.293
4	(Constant)	48.626	13.546	
	K_EMT	1.292	.392	.322
	K_B	–43.468	10.190	–1.070
	K_LT	–52.352	15.510	–.320
	K_HG	.992	.328	.740

Table 4
Coefficients for Sensory Properties

Equations		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta
5	(Constant)	79.803	7.235	
	COM_RR	–11.188	1.031	–.848
6	(Constant)	93.112	7.315	
	COM_RR	–9.022	1.079	–.684
	GRAINY	–4.230	1.132	–.306
7	(Constant)	123.903	10.957	
	COM_RR	–8.471	.978	–.642
	GRAINY	–4.001	1.014	–.289
	GRITTY	–4.030	1.150	–.222
8	(Constant)	100.313	12.623	
	COM_RR	–6.399	1.120	–.485
	GRAINY	–4.282	.933	–.309
	GRITTY	–3.626	1.062	–.200
	TEN_STR	1.984	.644	.232
9	Constant	84.991	13.796	

	Unstandardized Coefficients		Standardized Coefficients
Equations	B	Std. Error	Beta
COM_RR	–5.908	1.090	–.448
GRAINY	–4.140	.893	–.299
GRITTY	–3.917	1.021	–.216
TEN_STR	1.763	.622	.206
FUZZY	3.171	1.391	.137

References:

[1] Sztandera L. M. 2008, “Predicting Tactile Fabric Comfort from Mechanical and Handfeel Properties Using Regression Analysis,” *WSEAS Transactions on Computers*, under review.

[2] DeJong S. and Postle, R. 1977, “An Energy Analysis of Woven-Fabric Mechanics by Means of Optical-Control Theory Part II: Pure-Bending Properties,” *J Text Inst*, 68, 62–69.

[3] Ghosh, T. K., Batra, S. K., and Barker, R. L. 1990a, “The Bending Behavior of Plain-Woven Fabrics Part I: A Critical Review,” *J Text Inst*, 81(3), 245–255.

[4] Ghosh, T.K., Batra, S.K., and Barker, R.L. 1990b, “The Bending Behavior of Plain-Woven Fabrics Part II: The Case of Bilinear Thread-Bending Behavior and the Effect of Fabric Set,” *J Text Inst*, 81(3), 255–277.

[5] Behery, M. H., 2005, *Effect of Mechanical and Physical Properties on Fabric Hand*, Woodhead Publishing Limited, Cambridge, England.

[6] Karthikeyan, B. and Sztandera, L.M. 2007, “Sensory Perceptions of Fabrics: Analysis of Textile Comfort Properties using Statistical and Artificial Intelligence Techniques,” in *Proceedings of the 10th International Conference on Intelligent Systems*, Cambridge, MA, IASTED, 502-090, 149–154.

[7] Wong, A.S.W., Li, Y., Yeung, P.K.W., 2003, “Neural Network Predictions of Human Psychological Perceptions of Clothing Sensory Comfort,” *Text Res J*, 73(1), 31–37.

[8] Wong, A.S.W., Li, Y., Yeung, P.K.W., 2004, “Predicting Clothing Sensory Comfort with Artificial Intelligence Hybrid Model,” *Text Res J*, 74(1), 13–19.

[9] Cardello, V. A., Winterhalter, C., and Schutz, G. H., 2003, “Predicting the Handle and Comfort of Military Clothing Fabrics from Sensory and Instrumental Data: Development and Application of New Psychophysical Methods,” *Text Res J*, 73(3), 221–237.

[10] Radonja, P., Stanković, S., Dražić, D., and Matović, B., 2007, "Development and construction of Generalized process models by using Neural Networks and Multiple Linear Regression", *WSEAS Transactions on Systems*, 6(2), 287-293.

[11] M. Rocha, P. Cortez, and J. Neves, 2004, “Evolutionary Neural Network Learning Algorithms for Changing Environments”, *WSEAS Transactions on Systems*, 3(2), 596-601.

Acknowledgements:

This paper is based on a research project supported in whole by US Department of Defense/US Army Natick Soldier Research, Development & Engineering Center grant W911QY-04-1-0001.

The author would like to acknowledge Contracting Officer Technical Representative, Carole Winterhalter, Warfighter Science, Technology & Applied Research Directorate, U.S. Army Natick Soldier Research, Development & Engineering Center, Natick, MA, for her support throughout this project; as well as Dr. Howard Schutz, Professor Emeritus of Consumer Sciences, University of California-Davis, CA, and Visiting Scientist, U.S. Army Natick Soldier Research, Development & Engineering Center, Natick, MA; and Dr. Armand Cardello, Senior Research Scientist, U.S. Army Natick Soldier Research, Development & Engineering Center, Natick, MA, for their valuable feedback and support.

Data collection was done by Janet Brady, Laboratory for Engineered Human Protection, Philadelphia University, PA; data pre-processing was done by Joe DiMezza, undergraduate student at Philadelphia University.

Table 5
Excluded Mechanical Variables

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	K_LT	-.384(a)	-3.411	.001	-.457	.890
	K_WT	-.895(a)	-1.837	.073	-.267	.056
	K_RT	-.061(a)	-.471	.640	-.071	.850
	K_B	-.437(a)	-4.098	.000	-.526	.907
	K_HB	-.374(a)	-3.420	.001	-.458	.942
	K_G	-.385(a)	-3.454	.001	-.462	.899
	K_HG	-.309(a)	-2.749	.009	-.383	.963
	K_HG5	-.349(a)	-3.099	.003	-.423	.922
	K_LC	.033(a)	.260	.796	.039	.905
	K_WC	.188(a)	1.577	.122	.231	.944
	K_RC	-.090(a)	-.755	.454	-.113	.987
	K_MIU	.130(a)	1.083	.285	.161	.961
	K_MMD	-.189(a)	-1.580	.121	-.232	.936
	K_SMD	-.325(a)	-2.836	.007	-.393	.916
	K_TO	-.014(a)	-.115	.909	-.017	.953
	K_W	-.331(a)	-3.011	.004	-.413	.976
2	K_LT	-.293(b)	-2.841	.007	-.398	.836
	K_WT	-.911(b)	-2.210	.032	-.319	.056
	K_RT	-.128(b)	-1.158	.253	-.174	.832
	K_HB	.793(b)	1.814	.077	.267	.051
	K_G	-.020(b)	-.094	.926	-.014	.223
	K_HG	.661(b)	2.438	.019	.349	.126
	K_HG5	.321(b)	1.200	.237	.180	.142
	K_LC	.034(b)	.315	.754	.048	.905
	K_WC	.174(b)	1.706	.095	.252	.943
	K_RC	-.080(b)	-.783	.438	-.119	.986
	K_MIU	.111(b)	1.072	.290	.161	.959
	K_MMD	-.029(b)	-.249	.805	-.038	.798
	K_SMD	-.173(b)	-1.505	.140	-.224	.755
	K_TO	.082(b)	.764	.449	.116	.909
	K_W	-.092(b)	-.666	.509	-.101	.545
3	K_WT	-.218(c)	-.382	.704	-.059	.028
	K_RT	-.172(c)	-1.682	.100	-.251	.817
	K_HB	.820(c)	2.039	.048	.300	.051

	K_G	.200(c)	.940	.353	.143	.196
	K_HG	.740(c)	3.028	.004	.423	.125
	K_HG5	.552(c)	2.224	.032	.325	.132
	K_LC	.012(c)	.123	.903	.019	.900
	K_WC	.095(c)	.923	.361	.141	.843
	K_RC	-.040(c)	-.417	.679	-.064	.964
	K_MIU	.056(c)	.560	.578	.086	.916
	K_MMD	.023(c)	.213	.833	.033	.775
	K_SMD	-.156(c)	-1.457	.152	-.219	.752
	K_TO	-.042(c)	-.381	.705	-.059	.753
	K_W	-.214(c)	-1.635	.110	-.245	.500
4	K_WT	-.291(d)	-.556	.581	-.086	.028
	K_RT	-.116(d)	-1.194	.239	-.183	.781
	K_HB	.158(d)	.318	.752	.050	.031
	K_G	-.301(d)	-1.192	.240	-.183	.116
	K_HG5	-.303(d)	-.625	.535	-.097	.032
	K_LC	.012(d)	.127	.900	.020	.900
	K_WC	.081(d)	.862	.394	.133	.841
	K_RC	-.007(d)	-.075	.941	-.012	.948
	K_MIU	-.021(d)	-.221	.826	-.035	.847
	K_MMD	-.049(d)	-.485	.630	-.076	.732
	K_SMD	-.054(d)	-.505	.616	-.079	.654
	K_TO	.006(d)	.062	.951	.010	.734
	K_W	-.011(d)	-.073	.942	-.011	.345

Notes: a Predictors in the Model: (Constant), K_EMT; b Predictors in the Model: (Constant), K_EMT, K_B; c Predictors in the Model: (Constant), K_EMT, K_B, K_LT; d Predictors in the Model: (Constant), K_EMT, K_B, K_LT, K_HG; e Dependent Variable: COMFORT

Table 6
Excluded Handfeel Variables (f)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	GRITTY	-.239(a)	-3.273	.002	-.439	.948
	GRAINY	-.306(a)	-3.738	.001	-.487	.712
	FUZZY	.150(a)	1.795	.079	.258	.834
	THICK	.101(a)	1.083	.284	.159	.704
	TEN_ST	.231(a)	2.355	.023	.331	.575

	R					
	H_FRIC	-.066(a)	-.842	.404	-.125	.992
	F_F_FRIC	-.052(a)	-.653	.517	-.097	.963
	D_DEPTH	-.003(a)	-.034	.973	-.005	.940
	SPRING	.022(a)	.284	.778	.042	1.000
	F_GATHER	.051(a)	.564	.575	.084	.747
	F_COMP	.054(a)	.599	.552	.089	.767
	FULL_B	.003(a)	.026	.980	.004	.616
	STIFF	-.397(a)	-2.852	.007	-.391	.273
	COM_RES	.162(a)	.958	.343	.141	.214
	NOIS_I	.155(a)	.914	.365	.135	.212
	NOIS_PI	.011(a)	.101	.920	.015	.555
2	GRITTY	-.222(b)	-3.503	.001	-.467	.944
	FUZZY	.137(b)	1.860	.070	.270	.832
	THICK	.194(b)	2.399	.021	.340	.656
	TEN_STR	.264(b)	3.166	.003	.431	.571
	H_FRIC	.027(b)	.365	.717	.055	.871
	F_F_FRIC	-.047(b)	-.666	.509	-.100	.963
	D_DEPTH	.048(b)	.659	.513	.099	.908
	SPRING	.032(b)	.452	.653	.068	.999
	F_GATHER	.099(b)	1.233	.224	.183	.729
	F_COMP	.101(b)	1.272	.210	.188	.749
	FULL_B	.084(b)	.931	.357	.139	.582
	STIFF	-.278(b)	-2.092	.042	-.301	.251
	COM_RES	.217(b)	1.465	.150	.216	.212
	NOIS_I	.060(b)	.390	.698	.059	.206
	NOIS_PI	-.083(b)	-.867	.390	-.130	.518
3	FUZZY	.164(c)	2.554	.014	.363	.823
	THICK	.212(c)	3.022	.004	.419	.653
	TEN_STR	.232(c)	3.079	.004	.425	.562
	H_FRIC	.176(c)	2.483	.017	.354	.676
	F_F_FRIC	.135(c)	1.750	.087	.258	.613
	D_DEPTH	.048(c)	.741	.463	.112	.908
	SPRING	.044(c)	.710	.482	.108	.995
	F_GAT	.116(c)	1.635	.109	.242	.726

	HER					
	F_COMP	.121(c)	1.727	.091	.255	.745
	FULL_B	.140(c)	1.738	.089	.256	.563
	STIFF	-.134(c)	-1.002	.322	-.151	.214
	COM_RES	.251(c)	1.926	.061	.282	.211
	NOIS_I	.137(c)	.998	.324	.150	.201
	NOIS_PI	-.031(c)	-.355	.724	-.054	.502
4	FUZZY	.137(d)	2.280	.028	.332	.803
	THICK	.150(d)	2.041	.048	.300	.550
	H_FRIC	.123(d)	1.745	.088	.260	.613
	F_F_FRIC	.139(d)	1.985	.054	.293	.612
	D_DEPTH	-.006(d)	-.101	.920	-.016	.828
	SPRING	.001(d)	.011	.991	.002	.933
	F_GATHER	.116(d)	1.794	.080	.267	.726
	F_COMP	.117(d)	1.836	.073	.273	.744
	FULL_B	.077(d)	.979	.333	.149	.513
	STIFF	-.039(d)	-.306	.761	-.047	.200
	COM_RES	.240(d)	2.021	.050	.298	.210
	NOIS_I	.084(d)	.655	.516	.101	.197
	NOIS_PI	-.012(d)	-.154	.878	-.024	.499
5	THICK	.061(e)	.566	.574	.088	.252
	H_FRIC	-.054(e)	-.383	.704	-.060	.152
	F_F_FRIC	.067(e)	.756	.454	.117	.376
	D_DEPTH	-.034(e)	-.550	.585	-.086	.798
	SPRING	-.021(e)	-.359	.721	-.056	.909
	F_GATHER	.091(e)	1.418	.164	.216	.697
	F_COMP	.086(e)	1.349	.185	.206	.696
	FULL_B	-.021(e)	-.231	.818	-.036	.365
	STIFF	-.048(e)	-.395	.695	-.061	.200
	COM_RES	.164(e)	1.314	.196	.201	.182
	NOIS_I	.103(e)	.846	.402	.131	.196
	NOIS_PI	.018(e)	.228	.821	.036	.485

Notes: a Predictors in the Model: (Constant), COM_RR; b Predictors in the Model: (Constant), COM_RR, GRAINY; c Predictors in the Model: (Constant), COM_RR, GRAINY, GRITTY;
d Predictors in the Model: (Constant), COM_RR, GRAINY, GRITTY, TEN_STR;
e Predictors in the Model: (Constant), COM_RR, GRAINY, GRITTY, TEN_STR, FUZZY
f Dependent Variable: COMFORT