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Cross-Cultural Comparison of Sound Sensation and Its Prediction Models for Korean Traditional Silk Fabrics

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Abstract: In this study, cross-cultural comparison of sound sensation for Korean traditional silk fabrics between Korea and America was performed and prediction models for sound sensation by objective measurements including sound parameters such as level pressure of total sound (LPT), Zwicker's psychoacoustic characteristics, and mechanical properties by Kawabata Evaluation System were established for each nation to explore the objective parameters explaining sound sensation of the Korean traditional silk. As results, Koreans felt the silk fabric sounds soft and smooth while Americans were revealed as perceiving them hard and rough. Both Koreans and Americans were pleasant with sounds of Gongdan and Newttong and especially Newttong was preferred more by Americans in terms of sound sensation. In prediction models, some of subjective sensation were found as being related mainly with mechanical properties of traditional silk fabrics such as surface and compressional characteristics.

Keywords: Cross-cultural comparison, Sound sensation, Mechanical property, Sound parameter, Traditional silk fabrics, Prediction model

Introduction

Sounds generating from textile products have been recently considered as an important feature determining consumers' satisfaction as well as tactile and visual aesthetic performance according to textile end uses and wear situations. Therefore, auditory sensorial properties of fabrics have been discussed in some publications [1-3]. Through these works, subjective sensation for fabric sounds have been reported as being affected by related objective sound parameters and mechanical properties of fabrics including Kawabata Evaluation System [4]. These findings support Fabric Objective Measurements [5] of which principal aim is to identify and assess quantitatively the properties that contributes to the sensorial aspects of fabric and garment quality.

Since earlier stages for researching sensorial assessment of fabrics, dependence of subjective judgment on time and place, and personal and racial predilections has been pointed out [6]. Subjective sensation for fabric sounds may also vary with cultural and national backgrounds. Although some studies [7-9] have been reported on national comparison of fabric tactile hands, auditory sensorial attributes of textiles considering subjects' variables have been yet rare except a few works [10,11]. Especially there are no findings dealing with international comparison of auditory sensation on textiles for specific end uses.

Silk fabrics have been distinguished by their scrooping sounds as well as their characteristic luster, vivid color, and drape [12]. In Asian history, scrooping sounds from traditional silk fabrics have been regarded as pleasant to ear. Meaningful descriptors for fabric hands developed in Japan such as Kawabata's Evaluation include some expressions on sound caused by rubbing fabrics [5]. In addition, traditional silk fabrics in Asian areas have been manufactured somewhat differently from those in western in yarn preparation and weaving [13], resulting in their characterized mechanical properties considered to be related with sound properties. However any attempt for international comparison of aural sensory measurements for the traditional silk fabrics has been not performed yet. Therefore, the purpose of this study is to perform national comparison of sound sensorial aspects for Korean traditional silk fabrics. First, objectively measurable characteristics for fabric rubbing sounds are investigated. In addition, subjective sensory attributes on the fabric sounds evaluated by both Koreans and Americans are compared with each other. Finally, sensation prediction models for both two nations are established, respectively.

Experimental

Specimens

Eight different Korean traditional silk fabrics commercially available were selected considering current market trend [14]. The characteristics of specimens were shown in Table 1. All of specimens were woven fabrics consisted of 100 % silk filament fibers. The specimens were categorized according to both western weave types and Korean traditional fabric names. For example, although both specimen F5 and F7 were included into plain fabrics by western weave type classification, F5 was Nobangju while F7 was Newttong by Korean traditional silk fabric categories. Among the specimens, F1 (Gapsa), F2 (Jinjusa), F5, and F6 (Nobangju) were woven by raw silk yarn of which sericin was not removed, which results in stiff and crisp hands following Korean traditional silk fabrication. On the other hands, two different Gongdan (F3 and F4) and another two kinds of Newttong (F7&F8) were made by degummed silk yarns.

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Table 1. Characteristics of specimens

Specimens	Woven structure	Density (warp × weft/inch^2)	Thickness (mm)	Weight (g/m^2)	Korean traditional fabric name
F1	Leno variation	43 × 55	0.11	38.70	Gapsa
F2		80 × 61	0.11	41.10	Jinjusa
F3	Satin	51 × 178	0.19	81.60	Gongdan
F4		91 × 66	0.14	93.80	
F5	Plain	46 × 81	0.16	52.00	Nobangju
F6		213 × 111	0.14	52.00	
F7		76 × 127	0.23	90.20	Newttong
F8		412 × 92	0.23	83.50	

Fabric Sound Generation and Recording

By using a measuring apparatus for fabric noise (MAFN, patent no. 2001-0212605) used in previous works [2,15], frictional sound of each specimen was generated in an anechoic chamber of which loudness of background noise and cutoff frequency were below 10 dB and 63 Hz respectively. It was also recorded by a Sound Quality System (Type 7698, B&K), which was calibrated with a sound level calibrator (Type 4231, B&K) before the recording. Recorded sounds were transformed into spectral curves by a FFT at frequencies ranging from 0 to 17250 Hz using the Sound Quality Program (ver 3.2, B&K).

Objective Parameters Analysis

As sound parameters in objective parameters for fabric sounds, level pressure of total sound (LPT) and three psychoacoustic characteristics including loudness[z], sharpness[z], and roughness[z] by Zwicker [16] were calculated to quantify frictional sound of the silk fabrics. The values of these sound parameters for each specimen were obtained using the BZ 5652 software as summarized in a previous study [15].

In addition, mechanical properties of specimens as another objective measurement of silk fabrics by using the Kawabata Evaluation System (KES) FB [4] including tensile, bending, shear, compression, and surface properties were measured.

Subjective Evaluation

Participants

A total of forty college students between 18 and 26 years of age who was recruited from a university population in Seoul evaluated sensory aspects of silk fabric sounds. Among them, twenty participants (9 male students, 11 female students) were Korean students while other twenty (12 male students, 8 female students) were American college students who visited Korea for the first time through a student exchange program. All of them were screened for normal hearing by determining auditory threshold according to 5 dB up and 10 dB down procedure [17].

Experimental Procedures

Each sound of the eight different silk fabrics was presented to each participant. To provide real sounds of fabrics to participants, a well-trained assistant for the study rubbed two-pieces of same silk fabrics placing them between his palms with a same velocity to that applied in the MAFN. Each participant was given aural stimuli only and was not able to see both the assistant and the sample fabric. The distance between each participant and the sound stimulus was about 2 m considering real situation for perceiving sounds from others' clothes. For each sound, the participants were asked to answer questions relating to their subjective auditory sensation. The questions dealt with sound sensation by Semantic Differential Scale (SDS) consisted of seven paired adjectives that have used in a preliminary study [1] : These included (a) hard-soft, (b) quiet-loud, (c) dull-sharp, (d) obscure-clear, (e) smooth-rough, (f) low-high, and (g) unpleasant-pleasant. The sounds were presented twice by orders previously determined randomly using the random number table for each subject.

Results

Objective Parameters of Traditional Silk Fabrics

Sound Parameters

As objective measurements for frictional sound of the silk fabrics, LPT and three variables of psychoacoustic characteristics including loudness[z], sharpness[z], and roughness[z] were obtained as presented in Table 2. In terms of LPT describing physical loudness of sound, the traditional silk fabrics showed the values ranging from 42.4 dB to 51.7 dB, which were higher than those for silk chiffon fabrics [18] while lower than those for some of silk satin [19]. Comparing other fiber-made fabrics such as wool and nylon [18], it could be said that traditional silk fabrics generated frictional sounds less loudly than wool gabardine and nylon taffeta. Of the traditional silk fabrics, F4 (Gongdan) showed the highest value for LPT while F5 (Nobangju) did the lowest one, which means that

Table 2. Sound parameters of specimens

Specimens	LPT (dB)	Loudness[z] (sone)	Sharpness[z] (acum)	Roughness[z] (asper)
F1	47.10	4.79	2.78	2.10
F2	46.70	4.39	2.99	2.15
F3	45.00	3.41	2.88	2.03
F4	51.70	5.25	3.11	1.84
F5	42.40	2.13	2.49	1.56
F6	45.30	2.01	2.07	1.67
F7	45.80	2.50	2.73	1.76
F8	47.40	3.03	1.94	1.93

F4 made sound most loudly among the specimens while F5 did least loudly in term of physical strength for acoustic loudness. Similar to the range of LPT, the loudness[z] value was the highest for F4 (Gongdan) as 5.25 sone and the lowest for F6 (Nobangju) as 2.01 sone. The traditional silk fabrics tended to have higher levels for loudness[z] than other fiber type fabrics such as wool and polyester with similar LPT values to those of them. This means that frictional sounds of Korean traditional silk fabrics may be heard more loudly in terms of psychoacoustic consideration rather than physical aspect. On the other hands, even among the fabrics with same structure such as F3 and F4, they showed somewhat different values for LPT and loudness[z] from each other as described in Table 2. This might be due to the differences in some of mechanical properties, thickness, and weight between them. For example, one of Gongdan fabrics, F3 which was thicker and lighter than another Gongdan, F4, was more easily deformable at shearing and smoother in surface as presented in Table 3. Therefore, sound characteristics of the Korean traditional silk fabrics could be said to be different from one another even though their woven structures are identical.

For sharpness[z], F4 (Gongdan) showed the highest value as well as it has the highest one for loudness[z]. On the other hand, F8 (Newttong) was found as having the lowest value for sharpness[z] as 1.94 acum, which leads to the fact that the fabric generated sound less sharply in Zwicker's spychoacoustic aspects than any other fabrics that have reported in previous works [18,19]. Roughness[z] ranged between 1.56-2.15 asper which were similar level to other silk woven fabrics investigated in some a previous study [19].

Mechanical Properties

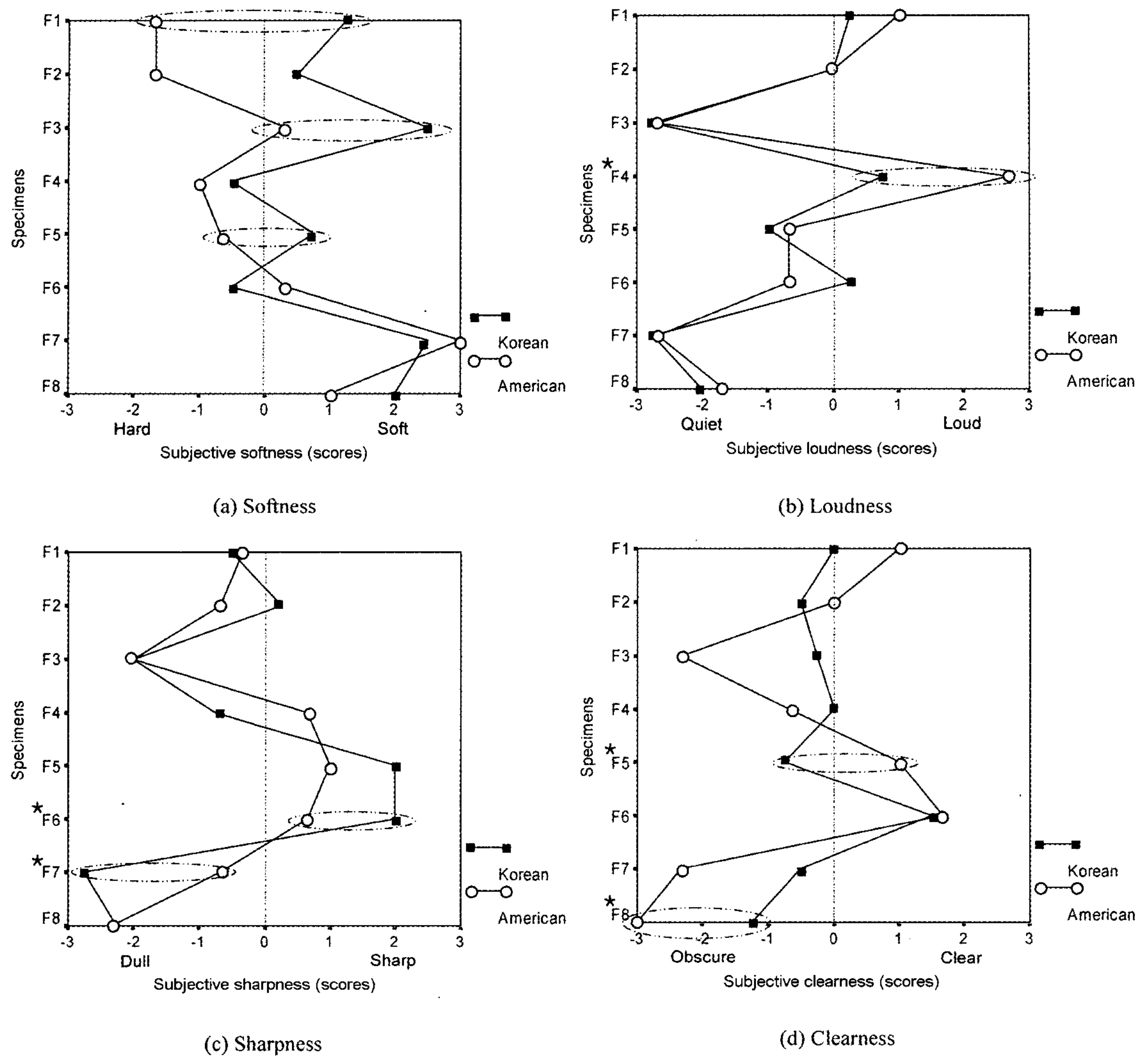
As another objective measurement, mechanical properties of specimens by KES-FB were obtained as presented in Table 3. Except two different Newttongs (F7&F8), all of the Korean traditional silk fabrics were found to be more rigid against bending because they showed much higher bending rigidity (B) than normal silk fabrics such as chiffon and georgette did [18]. This might be resulted from the fact that some of traditional silk fabrics such as Gapsa, Jinjusa, and Nobangju were made of gummed filament yarns of which sericin was not removed. Moreover, Gongdan fabrics which also gave higher bending rigidity values were very densely weaved and thicker than normal silk fabrics. In addition, surface properties of traditional silk fabrics were different from those of normal woven fabrics in the fact that values for both coefficient of friction (MIU) and geometrical roughness (SMD) were much higher. It means that most of the Korean traditional silk fabrics could be slip less easily to each other and be more irregular in surface depth due to their sericin unresolved, weave variations, and additional embroideries.

Cross-Cultural Comparison of Sensory Evaluation for Traditional Silk Fabric Sounds

The means of each sound sensation by both Koreans and Americans for eight different traditional silk fabrics are shown respectively in Figure 1. In terms of subjective softness as given in Figure 1(a), two different nations were found as not having many similarities in evaluating sound sensation of the fabrics. Koreans tended to perceive frictional sounds

Table 3. Mechanical properties of specimens

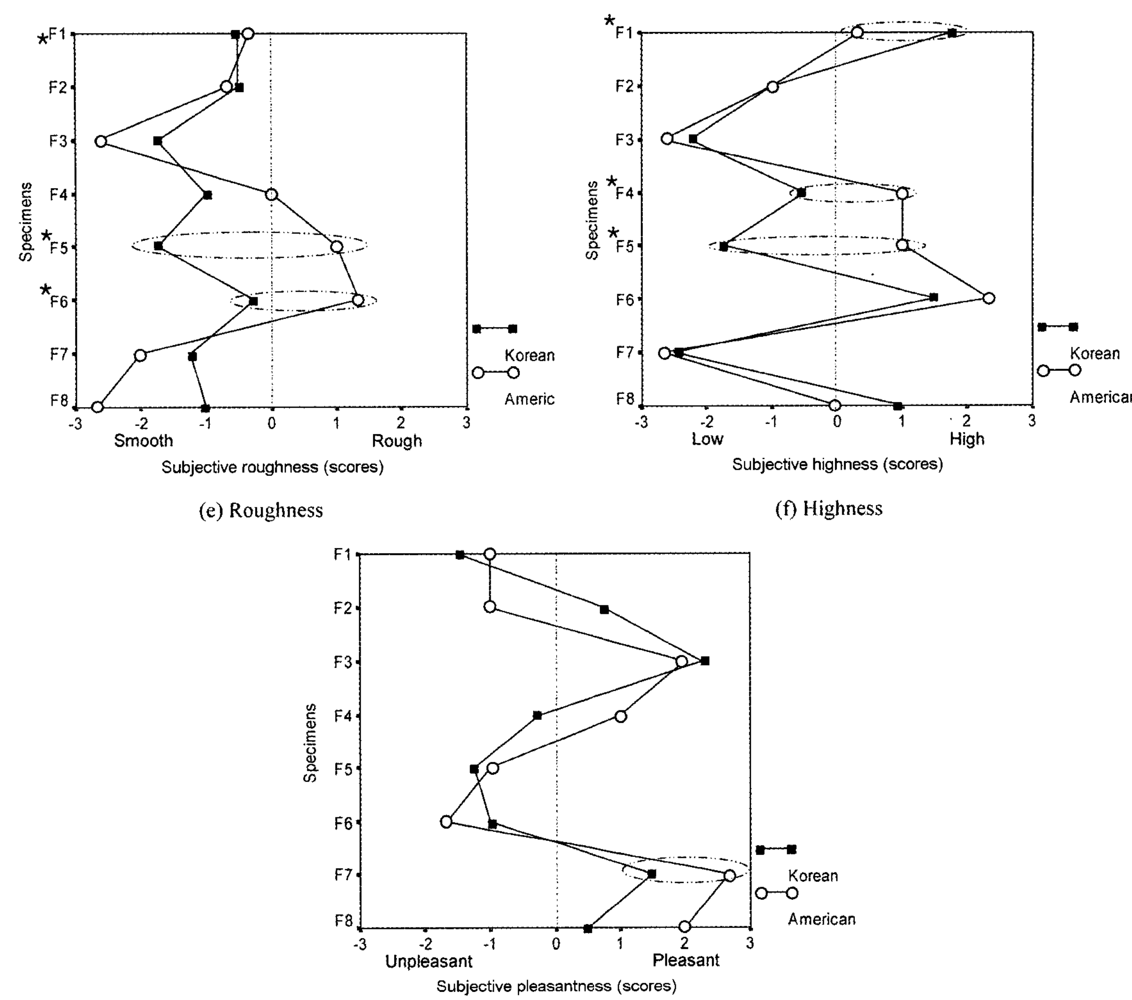
Specimens	Mechanical properties										
	Bending		Shear			Compressional			Surface		
	B (gf.cm^2/cm)	2HB (gf.cm/cm)	G (gf/cm.degree)	2HG (gf/cm)	2HG5 (gf/cm)	LC	WC (gf.cm/cm^2)	RC (%)	MIU	MMD	SMD (micron)
F1	0.13	0.05	0.91	0.05	5.41	0.28	0.05	61.70	0.92	2.55	5.04
F2	0.22	0.07	0.37	0.07	1.43	0.54	0.05	67.39	0.96	2.44	5.50
F3	0.07	0.08	0.37	0.08	1.49	0.50	0.07	47.14	1.70	1.03	1.82
F4	0.17	0.06	1.25	0.06	6.92	0.36	0.08	54.55	1.00	1.37	3.10
F5	0.19	0.08	0.26	0.04	0.48	0.38	0.04	64.86	1.14	2.33	6.38
F6	0.18	0.07	0.37	0.08	0.98	0.41	0.05	62.00	1.12	5.11	5.10
F7	0.03	0.01	0.21	0.01	0.26	0.41	0.07	47.22	1.68	1.65	1.97
F8	0.03	0.01	0.21	0.01	0.26	0.47	0.08	50.60	1.63	1.93	4.24



* Means p<.05 in t-test

Figure 1. Subjective sensation for sounds of specimens.

of the silk fabrics as soft, while Americans tended to perceive it hard. Precisely, Koreans answered that all of fabrics except F4 (Gongdan) and F6 (Nobangju) sounded soft rather than hard. On the contrary, Americans felt that many of the silk fabrics generated sounds hard rather than soft. Of the silk fabrics, F1 (Gapsa, $t = -4.62$), F3 (Gongdan, $t = -4.91$) and F5 (Nobangju, $t = -3.04$) revealed significant differences in scores for subjective softness between nations, by using t-test. In the case of F1 (Gapsa), Koreans felt it sounding soft, while Americans evaluated it sounding hard. It could be said that Koreans may perceive sound from Gapsa more familiar than Americans do, which results more positive evaluation of Koreans on the silk fabric. For subjective loudness, both Koreans and Americans seemed to evaluate many of the fabrics such as Newttong (F7&F8) and Nobangju (F5&F6) as sounding quiet rather than loud as shown in Figure 1(b). In measurements of the objective sound characteristics of F8 (Newttong), it showed similar value for LPT (47.40 dB) to F1 (Gapsa), but was rated as sounding quiet rather than loud, while F1 (Gapsa) as sounding loud a little bit because loudness [z] value was much lower for F8 (Newttong) than for F1 (Gapsa). There are significant differences between the two nations in subjective loudness for F4 (Gongdan, $t = 3.04$), which indicates that Americans perceived sounds from the Gongdan more loudly than Koreans did. On the other hand, as given in Figure 1(c), sounds from two types of Nobangju fabrics (F5&F6) were rated as sharp rather than dull while those from other fabrics including Gapsa(F1), Gongdan(F3), and Newttong (F7&F8) as dull by both two nations. Also sounds from one of Nobangju fabrics (F6) were perceived sharper significantly by Koreans than they were by Americans. For subjective clearness in Figure 1(d), two nations did not



(e) Roughness

(f) Highness

(g) Pleasantness

Figure 1. Continued.

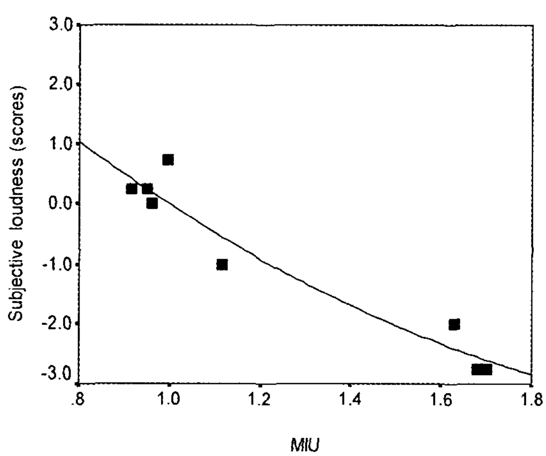
show many similarities in rating the eight silk fabrics supporting the results of the preliminary work [10] that subjective clearness of fabric sound was not consistent according to subjects' nation. There are significant differences in clearness scores for F5 (Nobangju, $t = -7.58$) and F8 (Newttong, $t = -5.92$) between the two nations. Another type of Nobangju (F6) fabrics gave the highest scores for clearness by both Koreans and Americans. As for subjective roughness, Koreans evaluated all of the fabrics as sounding smooth rather than rough as presented in Figure 1(c). On the contrary, Americans perceived sounds from both two Nobangju (F5, $t = -2.65$ &F6, $t = 3.10$) as rough, which derived significant differences in the scores for each fabric between Koreans and Americans. Subjective highness scores for the traditional silk fabrics also showed significant differences between the two nations in sounds from F1 (Gapsa, $t = -3.49$), F4 (Gongdan, $t = 4.39$), and F5 (Nobangju, $t = -0.87$) as described in Figure 1(f). Especially, in the case of F4 and F5, Koreans evaluated their sounds as low while Americans did high. Finally, as for pleasantness, F1 (Gapsa) and two different Nobangju (F5& F6) received negative scores for pleasantness by both two nations, which means that sounds from them were unpleasant subjectively. Both Koreans and Americans gave positive scores for F3 (Gongdan) and two types of Newttong (F7& F8), which implies that they perceived sound from the fabrics to be pleasant. Especially, Americans evaluated significantly sound from F7 (Newttong, $t = 2.65$) as more pleasant than Koreans did.

Some of Korean traditional silk fabrics such as F1 (Gapsa) and F5 (Nobangju) were evaluated as sounding differently between the two nations. Precisely, Gapsa (F1) was rated as sounding soft by Koreans, while it hard by Americans. In the case of Nobangju (F5), Koreans perceived its sound as soft, obscure, smooth, and low. On the contrary, Americans felt its sound as hard, clear, rough, and high. These results might be correlated with the statements in a previous study [19] that Americans felt that the sound from silk was coarser and stronger than Koreans did. In addition, as mentioned above, gummed or heavily sized silk such as Gapsa and Nobangju have been familiar to Koreans, which leads to the results that Koreans answered more positively in terms of the sound sensation.

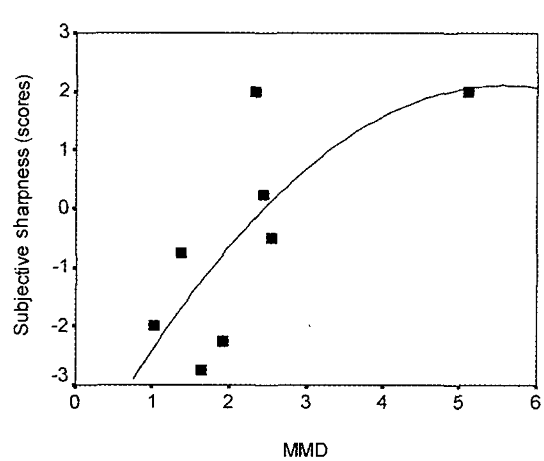
Cross-Cultural Comparison of Prediction Models for Fabric Sound Sensation

To establish prediction models for sound sensation by the objective measurements for the traditional silk fabrics, multiple stepwise regression was performed by using both sound parameters and mechanical as independent variables and by using subjective sensation as dependent ones. For Koreans, four aspects of sound sensation including softness, loudness, sharpness, and pleasantness were regressed significantly by the objective measurements. For Koreans, subjective softness was explained positively by coefficient of friction (MIU), which means that Koreans rated silk fabrics with higher MIU as sounding softer (Y = 2.92 **MIU** + 1.43, R^2 = 0.70). As for subjective loudness by Koreans, both MIU and LPT appeared as significant predictors (Y = −3.39 **MIU** + 0.18 **LPT** − 1.51, R^2 = 0.99). As the silk fabrics had higher LPT, physical loudness for fabric sound, they were perceived as providing sounds more loudly. This result is supported by the fact that F4 (Gongdan) with the highest LPT value among the fabrics was rated as sounding more loudly than any other fabrics as shown in Figure 1(b). In addition, Figure 2(a) explained the relationship between MIU and loudness by Koreans that traditional silk fabrics having lower MIU values were evaluated as generating sounds louder. It implies that the traditional silk fabrics that rubbed more easily consuming less physical energy seemed to be perceived as sounding louder. However, this result should be considered only for Korean traditional silk fabrics because for other materials frictional coefficient tends to be proportional to frictional noise. Subjective sharpness by Koreans was regressed significantly by both mean deviation of MIU (MMD) and bending rigidity (B) (Y = 0.74 **MMD** + 13.42 **B** − 0.07, R^2 = 0.93). The equation means that fabrics having higher values for MMD tended to be rated as sounding sharper as described in Figure 2(b). As for subjective clearness, roughness, and highness, no objective measurement entered prediction models. Subjective pleasantness by Koreans was revealed to have four significant predictors such as coefficient of friction (MIU), sharpness(z), compressional linearity (LC), and tensile recovery (RT) (Y = 3.59 **MIU** + 1.51 **sharpness(z)** + 7.35 **LC** + 0.06 **RT** − 10.90, R^2 = 0.99). All of these predictors affected positively subjective pleasantness. For proofing that MIU affected positively pleasantness, F3 (Gongdan) and F7 (Newttong) with higher MIU values than other fabrics could be examples.

On the other hand, for Americans, some of sound sensation were also were predicted by the objective measurements. As for softness, fabric thickness (T) was the only significant predictor (Y = 28.76 **T** − 0.75, R^2 = 0.75). Figure 3(a) describes the relationship between fabric thickness (T) and subjective softness by Americans that silk fabrics thicker seemed to be felt as sounding softer. This result could be due to the traditional fabrication methods for Korean silk fabrics in which fabrics made by raw silk yarn are generally weaved both less thickly and more stiffly than other silk fabrics. Subjective loudness by Americans was affected significantly by both bending hysteresis (2HG5) and compressional recovery (RC) (Y = 0.37 **2HG5** + 0.12 **RC** − 4.23, R^2 = 0.75). That is, as the silk fabrics were less recoverable at shear deformation, they tended to be rated as making sounds louder (see Figure 3(b)). In addition, as more recoverable at compression the fabrics, they were also inclined to be perceived as sounding louder. Subjective clearness, roughness, and highness answered by Americans were regressed significantly by some of objective measurements while the sensation by Koreans was not predicted by any objective characteristics as mentioned above. Subjective clearness had the regression equation in

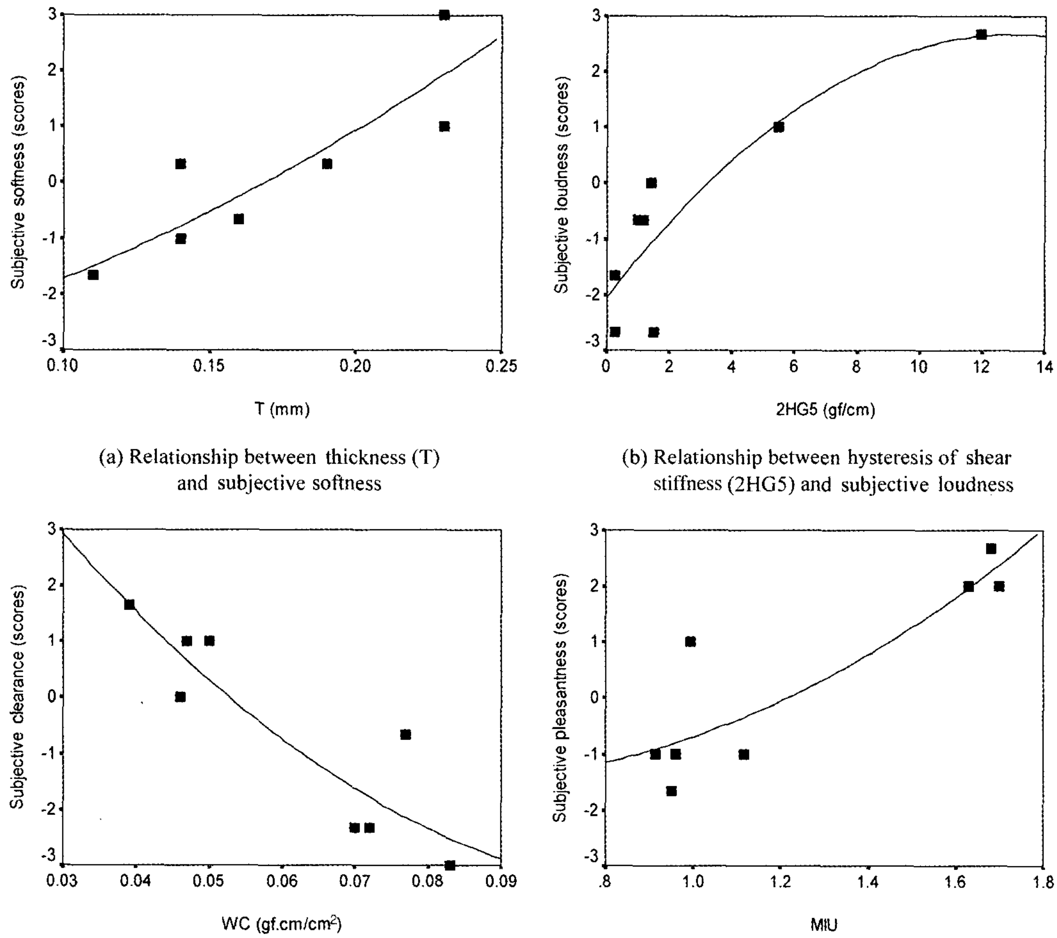


(a) Relationship between coefficient of friction (MIU) and subjective loudness



(b) Relationship between mean deviation of MIU (MMD) and subjective sharpness

Figure 2. Relationships between objective measurements and subjective sensation by Koreans.



(a) Relationship between thickness (T) and subjective softness

(b) Relationship between hysteresis of shear stiffness (2HG5) and subjective loudness

(c) Relationship between compressional energy (WC) and subjective clearness

(d) Relationship between coefficient of friction (MIU) and subjective pleasantness

Figure 3. Relationships between objective measurements and subjective sensation by Americans.

which both coefficient of friction (MIU) and compressional energy (WC) entered (Y = –2.63 **MIU** – 54.99 **WC** + 10.01, R^2 = 0.91). As an example, the relationship between subjective clearness and compressional energy (WC) is presented in Figure 3(c). Actually, F6 (Nobangju) with the lowest WC value was rated as sounding clearer than any other traditional silk fabrics. On the contrary, F8 (Newttong) with the highest value for the physical properties was perceived as sounding least clearest among the fabrics. As for subjective roughness, coefficient of friction (MIU) and loudness(z) were found to be significant negative predictors, and hysteresis of shear force (2HG) to be a significant positive predictor, respectively (Y = –4.81 **MIU** – 1.00 **loudness[z]** + 0.21 **2HG** + 12.46, R^2 = 0.97). MIU also appeared as the only significant objective characteristics affecting negatively subjective highness by Americans (Y = –4.92 **MIU** + 9.53, R^2 = 0.71). Finally, subjective pleasantness by Americans was predicted powerfully (R^2 = 1.00) by sharpness[z] and some of physical properties such as compressional energy (WT), coefficient of friction (MIU), tensile energy (WT), and shear stiffness (G) (Y = 18.55 **WC** + 3.46 **MIU** + 0.70 **sharpness[z]** + 0.23 **WT** + 0.16 **G** – 4.01). This means that traditional silk fabrics that were bulkier and less consuming frictional energy, seemed to be evaluated as generating sounds more pleasant. Figure 3 (d) describes the positive relation between coefficient of friction (MIU) and subjective pleasantness by Americans.

Considering these results, it can be said that frictional sounds of Korean traditional silk fabrics were affected mainly by their mechanical properties such as surface and compressional properties. It may be due to somewhat different method for yarn preparation and weaving process of the traditional silk fabrics from those of western silk fabrics.

Conclusions

In this study, subjective sensation for Korean traditional silk fabrics by both Koreans and Americans was investigated and the prediction models for sound sensation were established by using sound parameters and mechanical properties of the silk fabrics. As results, traditional silk fabrics were found as showing lower values for both physical loudness (LPT) and psychoacoustic sharpness[z] and than those of other fiber type fabrics such as wool and nylon. In addition, they were more rigid at bending and shear deformation and showed higher frictional forces and more irregular surface depth than other normal fabrics in terms of mechanical properties. For sensory measurements, Koreans were inclined to perceive sounds from traditional silk fabrics soft and smooth while Americans tended to feel them hard and rough, which could be because Koreans are familiar with traditional silk sounds and therefore liable to accept them more positively. However pleasantness for the fabric sounds showed similar trends between the two nations. Precisely, both Koreans and Americans evaluated Gongdan and Newttong fabrics as sounding pleasant. Especially Americans felt sounds from Newttong fabrics more pleasant than Koreans did. It could be said that Americans prefer sounds from traditional silk fabrics such as Newttong showing similar physical characteristics to normal silk ones.

The other conclusion worth pointing out is that sound sensation for traditional silk fabrics was affected strongly by mechanical properties such as surface and compressional features due to the characteristics of Korean silk yarns and their woven structures. Also, subjective pleasantness by both two nations was determined by many of the objective measurements. This means that auditory preference for Korean traditional silk fabrics may be related with more variety of the objective measurements not only physical loudness such as LPT which have appeared as a main descriptor for aural pleasantness for fabrics in some previous works [1].

It is worthwhile to further investigate whether Americans and Koreans show physiological responses significantly to traditional silk fabric sounds to provide more reliable evaluation systems for fabric sound quality. Moreover, touch sensation for Korean traditional silk fabrics needs to be investigated as totally sensible products for the global textile markets.

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