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Physical Factors Affecting Sound Sensation for Korean Traditional Silk Fabrics with Similar Sound Pressure Levels

유사 음압 전통 견직물의 소리 감각에 영향을 미치는 물리적 요인

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Abstract : This study was carried out to investigate sound sensation of Korean traditional silk fabrics with similar sound pressure levels (SPL) and to identify secondary physical factors excluding SPL which determine sound sensation of the fabrics. Sounds of the silk fabrics tended to be perceived differently from one another as for some of sensation such as clearness and roughness. They were felt more strongly in aspects of loudness, roughness, and highness than of softness, sharpness, clearness, and pleasantness. Subjective clearness, roughness, and highness were significantly correlated with some of sound parameters including roughness[z], ΔL, and Δf. Especially, both of clearness and roughness which were varied among the fabrics were found as determined by ΔL. This result means that ΔL as well as roughness[z] and Δf could be utilized secondary to SPL in order to satisfy some of human sensibility for sound from traditional silk fabrics without variation of physical loudness.

Key words : Similar sound pressure levels, Korean traditional silk fabrics, sound sensation, physical factor, sound color

요약 : 본 연구의 목적은 직물 소리의 주관적 감각을 결정하는 객관적 성질 중 가장 밀접한 관계를 지닌 것으로 보고되고 있는 물리적 음압 외에 직물 소리의 미세한 감각 차이를 설명할 수 있는 2차적 물성들을 규명하는 데에 있다. 3dB 이내의 유사 음압을 보이는 전통 견직물 다섯 종을 선택하여, 음향학적 물성치로 음색 요인인 ΔL과 Δf, 심리음향학적 요인인 sharpness[z], roughness[z], fluctuation strength를 측정하고, 직물의 역학적 성질로서 Kawabata Evaluation System (KES)의 17개 물성을 측정하였다. 주관적 감각은 자유식강도측정법에 의하여 부드

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러움과 시끄러움을 포함한 7개 감각을 평가하였다. 연구 결과, 유사음압의 전통 견직물의 소리에 대한 주관적 감각 중 객관적 물성과 유의한 상관관계를 보이는 감각은 맑음과 거침, 높음이었다. 견직물 소리 간에 차이를 보인 맑음과 거침은 음색 요인인 ΔL에 의해 영향을 받아서, ΔL 값이 큰 직물일수록 소리가 더 맑고 덜 거칠게 느껴지는 것으로 나타났다. 또한 주관적인 높음은 roughness[z]와 Δf와 유의적 상관관계를 나타내어, roughness[z] 값이 커질수록 또는 Δf 값이 작아질수록 소리가 더 높게 느껴지는 경향을 보였다. 따라서 유사음압의 전통 견직물의 소리 감각은 음압 외에 roughness[z]와 음색 요인들에 의하여 결정되며, 이를 전통 견직물의 소리 설계에 활용할 수 있을 것으로 기대된다.

주제어 : 유사음압, 한국전통견직물, 소리감각, 물리적 요인, 음색

1. INTRODUCTION

Auditory sensation and sensibility from apparel fabrics have been investigated through a series of works[5, 8, 9] in such varied respects as their fiber compositions, weaving structures, and specific end-uses, under the principal aim of identifying and assessing quantitatively the objective measurements such as mechanical properties and acoustic characteristics that contribute to the perception of fabric sound quality. In some of the previous studies[1, 2, 9], sound pressure level (SPL) as a objectively measurable attributes, has been frequently found as the primary factor determining subjective sensorial judgments of fabric sounds such as softness and pleasantness as well as loudness. Precisely, human seemed to be satisfied with fabric sounds as the fabrics made sounds with lower SPL. In addition, the SPL value of 50dB was revealed as a threshold for aural pleasantness of fabrics[9]. Although these results have provided fundamental information concerning human sensation and satisfaction for fabric sounds, at the same time, we might have overlooked other possible objective parameters which could be significantly entered in prediction models for fabric sounds under the conditions of minimizing SPL's affects. Therefore it needs to figure out additional meaningful physical properties next to SPL which affects sound sensation of fabrics of which physical loudness are not varied among them.

The unique sounds from silk have been considered as a significant attribute for evaluating total quality of the apparel products made of it. In Asia, the scrooping sounds from traditional silk fabrics have been regarded as pleasant to ear[4]. Asian traditional silk fabrics have been manufactured somewhat differently from those in western in yarn preparation and weaving[7]. It may be assumed that their structural and mechanical properties could be related with their auditory sensibility. Sounds from silk fabrics have been reported as less louder than other fibers [8], which results in the fact that they often have been perceived as more comfortable than others. Therefore, it is worth investigating auditory sensation of traditional silk fabrics having similar SPL values and establishing prediction models for sound sensation of the silk by secondary physical factors excluding SPL in order to describe more delicate aural comfort of the silk.

In this study, it was attempted first to evaluate subjective sensation for sounds from traditional

silk fabrics showing similar SPL values less than 50 dB within the variations of 3dB. Finally, physical factors determining sound sensation of the silk fabrics secondary to SPL were found out by establishing prediction models for the sensation.

2. EXPERIMENTAL

2.1 Fabric Selection

In order to choose the traditional silk fabrics for this study, thirty eight different Korean traditional silk fabrics commercially available were collected first. Each rubbing sound of them was analyzed by a Sound Quality System(Type 7698, B&K). The value for sound pressure level (SPL) of each sound was measured. The SPL values of the collected Korean traditional silk fabrics were ranged from 39.8dB to 60.6dB. In order to minimize the effects of sound loudness on subjective sensation, final five different fabrics for this study were selected so that their SPL were all within the variation of 3dB because human cannot detect loudness differences in that ranges [6] as well as they were less than 50dB. Finally, the SPL values of the selected traditional silk fabrics were ranged from 44.80 dB (NB1) to 47.10 dB (GS). The characteristics of the silk fabrics are summarized in Table 1.

2.2 Objective Fabric Analysis

In order to investigate objective sound parameters, besides SPL, sound color factors such as level range (ΔL), frequency difference (Δf) were quantified using equations mentioned in previous studies. In addition, the three variables of Zwicker's psycho-acoustics[11] including sharpness[z], roughness[z], and fluctuation strength were calculated with the BZ5652 software. As another category of objective fabric characteristics, mechanical properties of the fabrics were measured by using Kawabata Evaluation System (KES).

2.3 Subjective Sensation Evaluation

A total of thirty college students (15 male students, 15 female students) with normal hearing were recruited from a university population for subjective evaluation. A set of prerecorded fabric sounds was presented to each participant using a laptop computer. For each sound, each subject was asked to answer questions dealing with seven aspects of sound sensation (softness, loudness, sharpness, clearness, roughness, highness, pleasantness) developed in previous works[1, 2, 9]. The

Table 1. Characteristics of Traditional Silk Fabrics

Fabrics	SPL (dB)	Woven Structure	Thickness (mm)	Weight (g/m^2)	Korean Traditional Fabric Name
GD	45.00	Satin	0.19	81.60	Gongdan
GS	47.10	Leno Variation	0.11	38.70	Gapsa
NB1	44.80	Plain	0.18	48.30	Nobangju
NB2	46.00		0.17	45.40	
MJ	46.40		0.08	44.80	Myoungju

questionnaire was structured in the form of Free Modulus Magnitude Estimation (FMME). In each sound presentation, each subject assigns a number to each of seven sensation and satisfaction so that high number represents high sensation and low number does low sensation[2].

Sensory measurements were repeated twice so that two responses are obtained for each subject and each sensation. Each subject was presented with five different sounds of fabrics in sequence. The order of sound presentation was previously determined using random number table for each subject.

3. RESULTS AND DISCUSSION

3.1 Objective Sound Parameters and Mechanical Properties

Table 2 shows the values for objective sound parameters of the Korean traditional silk fabrics. In terms of sound color factors which describes the characteristics of auditory spectrum shapes, the value for ΔL were the highest for NB2 (32.31dB) while the lowest for GS (14.13dB), which means NB2 had more steeper spectral shape than other fabrics. The other hands, as for Δf, all of fabrics showed negative values, which indicates that they have higher amplitudes at lower frequencies than at higher ones. Compared to the sound color factors, Zwicker's psychoacoustic parameters such as sharpness[z] and roughness[z] were not varied a lot among the silk fabrics in that they were ranged from 2.40 to 2.88 acum for sharpness[z] and from 2.03 to 2.33 asper for roughness[z], respectively.

As another objective measurement, the values for mechanical properties of the silk fabrics by KES-FB were presented in Table 3. Except GD and MJ, 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 because they were made of gummed filament yarns of which sericin was not removed. As for shear properties, GS woven by a specific leno variation showed the highest shear stiffness (G) while NB2 did the lowest. The values for shear stiffness (G) were more varied for the traditional silk fabrics than for other normal western silk fabrics.

3.2 Subjective Sound Sensation

Subjective sound sensation for Korean traditional silk fabrics with similar sound pressure level of

Table 2. Sound Parameters of Fabrics

Fabrics	ΔL (dB)	Δf (Hz)	Sharpness[z] (acum)	Roughness[z] (asper)	Fluctuation Strength (vacil)
GD	23.55	-3445.32	2.88	2.03	1.34
GS	14.13	-5297.16	2.78	2.10	1.42
NB1	26.30	-11929.40	2.77	2.33	1.10
NB2	32.31	-6503.03	2.40	2.27	0.51
MJ	25.06	-2196.39	2.41	2.03	1.55

Table 3. Mechanical Properties of Fabrics

Fabrics	GD	GS	NB1	NB2	MJ
EM (%)	1.64	1.99	1.86	1.50	2.03
LT (-)	0.82	0.75	0.78	0.82	0.76
WT (gf.cm/cm^2)	3.28	3.73	3.63	3.05	3.85
RT (%)	52.05	6.26	71.42	72.99	61.04
B (gf.cm^2/cm)	0.07	0.13	0.38	0.41	0.03
2HB (gf.cm/cm)	0.08	0.05	0.09	0.09	0.02
G (gf/cm.degree)	0.37	0.91	0.24	0.22	0.29
2HG (gf/cm)	1.29	1.40	0.03	0.03	0.13
2HG5 (gf/cm)	1.49	5.47	0.31	0.26	0.80
LC (-)	0.50	0.28	0.51	0.33	0.37
WC (gf.cm/cm^2)	0.07	0.05	0.05	0.04	0.03
RC (%)	47.14	61.70	62.56	75.00	58.62
MIU (-)	1.70	0.92	1.09	0.96	0.93
MMD (-)	1.03	2.55	2.76	2.57	1.52
SMD (micron)	1.82	5.04	6.40	9.89	4.93

50dB bellows was presented in Figure 1. The ratings for the traditional silk fabrics were larger for loudness, roughness, and highness than for softness, sharpness, clearness, and pleasantness. This means that the traditional silk fabrics with sound pressure level between 44.80 dB and 47.10 dB were felt as sounding stronger in terms of loudness, roughness, and highness than of softness, sharpness, clearness, and pleasantness. Therefore a future investigation needs for the subjective sound sensation of traditional silk fabrics with sound pressure level lower than 44dB. The other hands, sound sensation of silk fabrics in this study was more varied among the fabrics in subjective loudness, clearness, and roughness than in softness, sharpness, and pleasantness. This result was supported by the finding of a previous study [3] that normal western fabrics with similar SPL showed yet different sores for subjective loudness to one another. Precisely, Gongdan (GD) and Gapsa (GS) were evaluated as sounding louder, less clearer, and rougher while two different Nobangju (NB1 & NB2) were perceived as less louder and less rougher than other fabrics. Sound of NB1 was felt as more sharper and more clearer than any other fabrics.

3.3 Physical Factors Affecting Sound Sensation of Fabrics

In order to identify physical factors influencing subjective sound sensation of the traditional silk fabrics with similar SPL, regression models for sound parameters by mechanical properties and for subjective sensation by sound parameters were established, respectively. As results, among the sound parameters, roughness[z] and ΔL were found as being significantly related by some mechanical properties. Their relationship with mechanical properties are shown in Figure 2(a)

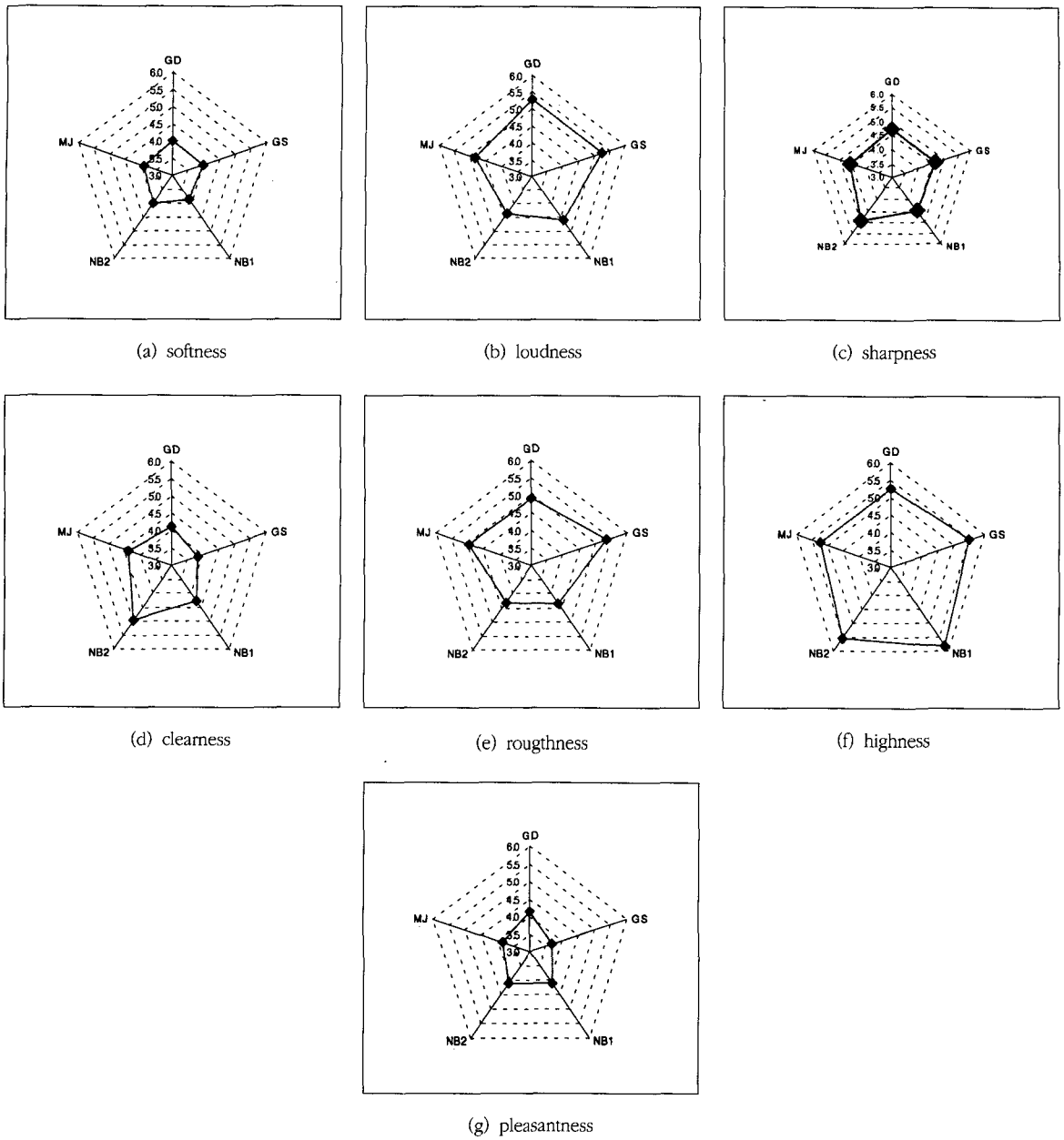
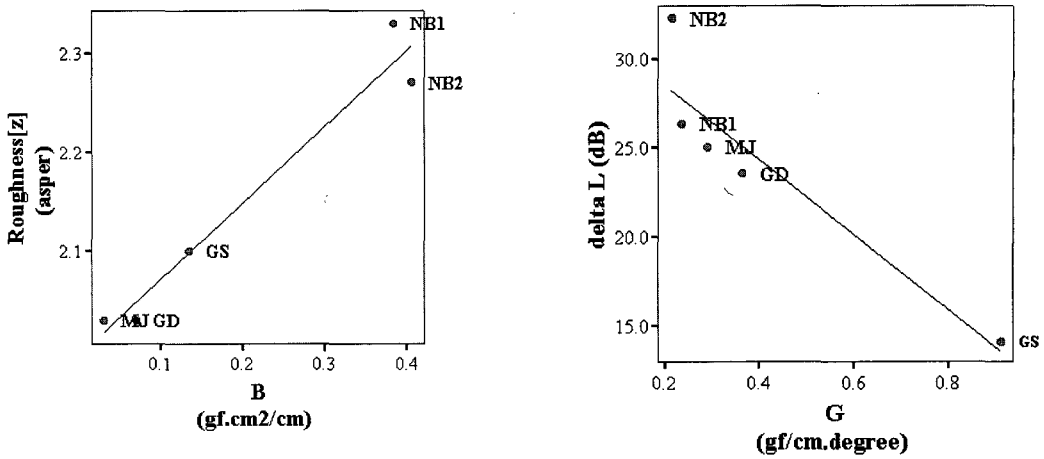


Figure 1. Subjective Sound Sensation of Fabrics

and (b), respectively. Roughness[z] was predicted by bending rigidity (B). Precisely, the silk fabrics with higher bending rigidity seemed to show higher roughness[z] in their sounds, as given in Figure 2(a). Actually, two different Nobangju fabrics (NB1 & NB2) having higher bending rigidiy values than other silk fabrics also showed higher roughness[z]. As for ΔL, shear stiffness (G) was found as a negative predictor, which means that the silk fabrics less resistant to shear deformation tended to have higher ΔL values(Figure 2(b)). Among the traditional silk fabrics, Gapsa (GS) was



(a) roughness[z] = 0.77**B** + 1.99, R^2 = 0.96

(b) ΔL = -21.10**G** + 32.79, R^2 = 0.86

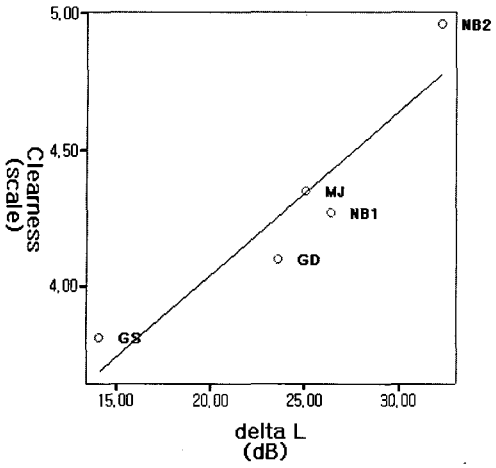
Figure 2. Sound Parameters Predicted by Mechanical Properties

revealed as having the lowest value for ΔL.

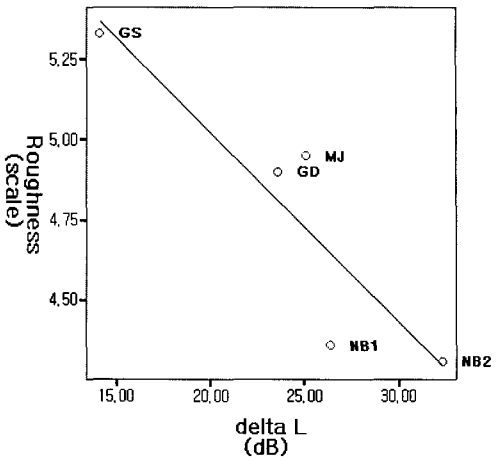
In terms of subjective sound sensation of traditional silk fabrics with similar SPL less than 50 dB, as given in Table 4, some of subjective sensation were significantly correlated with objective sound parameters. Precisely, clearness, roughness, and highness were explained by some parameters such as roughness[z] among psychoacoustic parameters, and sound color factors including both of ΔL and Δf. As for subjective clearness of sounds from the silk, it was positively correlated with ΔL. As the fabrics had higher ΔL values in their sound spectral wave, they seemed to sound clearer as shown in Figure 3(a). Subjective roughness of the silk's sounds was also correlated significantly with ΔL. The relationship between subjective roughness and ΔL was presented in Figure 3(b). The figure means that humans tended to feel th silk's sounds rougher as the fabrics had lower values for Δf. Subjective highness was significantly correlated with two of sound parameters, that is, roughness[z] and Δf. Roughness[z] affected positively subjective highness from the silk's sounds while Δf did it negatively. As given in Figure 3(c), the traditional silk fabrics had a tendency to be rated as sounding higher as their

Table 4. Correlation Coefficients between Subjective Sensation and Sound Parameters

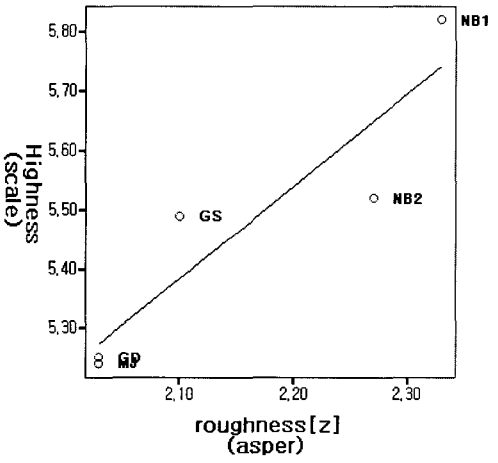
sound sensation / sound parameters	softness	loudness	sharpness	clearness	roughness	highness	pleasantness
sharpness[z]	-0.01	0.69	-0.28	-0.76	0.32	0.17	0.02
roughness[z]	-0.49	-0.77	0.16	0.49	-0.81	0.92*	0.43
fluctuation strength	-0.10	0.76	-0.75	-0.82	0.80	-0.45	-0.57
ΔL	-0.26	-0.83	0.36	0.93*	-0.90*	0.15	0.80
Δf	0.64	0.50	0.15	-0.13	0.63	-0.92*	-0.34



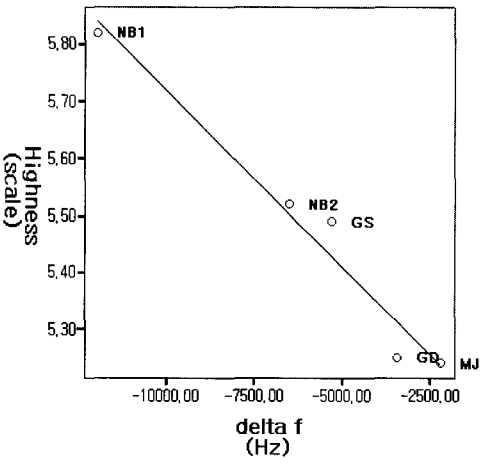
(a) **Clearness** = 0.06 ΔL + 2.84, R^2 = 0.87



(b) **Roughness** = -0.06 ΔL + 6.20, R^2 = 0.81



(c) **Highness** = 1.56 roughness[z] + 2.10, R^2 = 0.84



(d) **Highness** = -0.01 Δf + 5.10, R^2 = 0.96

Figure 3. Subjective Sound Sensation Predicted by Sound Parameters

values for roughness[z] got higher. The other hands, Figure 3(d) shows the effects of Δf on subjective highness. The silk fabrics seemed to be evaluated as making sounds higher as their values for Δf were lower. Both of them influenced positively subjective highness.

From the results discussed above, it could be summarized that subjective sound sensation of traditional silk fabrics with similar sound pressure levels was significantly described by sound parameters in terms of clearness, roughness, and highness. They are affected by such objective parameters as roughness[z], ΔL, and Δf. Nevertheless the effects of SPL and loudness[z], as loudness-related parameters, on fabric sound sensation were minimized in this study, it could be pointed out that clearness, roughness, and highness were explained powerfully by such

sound parameters. In a previous study for fabrics with similar sound pressure level, sound sensibility such as sharpness and highness of a fabric group containing wool, polyester, and silk was reported that it was affected by roughness[z] that is one of Zwicker's psychoacoustic parameters. Compared to the previous finding[3], it could be concluded that sound sensation of traditional silk fabrics with similar sound pressure levels less than 50dB was determined mainly by sound color factors including ΔL and Δf as well as roughness[z]. Especially, ΔL was the more useful predictor for sound sensation of the silk's sounds than other parameters because it determined both clearness and roughness.

4. CONCLUSIONS

In this study, sound sensation of some Korean traditional silk fabrics with similar sound pressures were investigated and the significant physical factors affecting the sensation were determined.

Sounds of the silk fabrics seemed to be perceived differently from one another as for loudness, clearness, and roughness although they have similar values in SPL. Also, most of the silk fabrics were scored higher in terms of loudness, roughness, and highness than of softness, sharpness, clearness, and pleasantness. Subjective clearness, roughness, and highness were significantly correlated with some of sound parameters including roughness[z], ΔL, and Δf. As the values for ΔL were higher, the traditional silk fabrics seemed to sound clearer and less rougher. The other hands, as roughness[z] was higher or Δf was lower, they had a tendency to be perceived as sounding higher. These results may lead to the conclusions that some of sound sensation for traditional silk fabrics which had similar sound pressure levels were determined by the secondary measurable physical factors such as roughness[z], ΔL, and Δf to sound pressure levels. Moreover, by manipulating the physical factors, sound sensory attributes which consumers require from the silk fabrics can be provided.

In future studies, other physical factors significantly related with sound sensation such as pleasantness for Korean traditional silk fabrics with similar levels need to be identified. Also traditional silk fabrics showing much lower SPL around 40dB should be investigated to figure out the relationship between their auditory sensibility and physical characteristics.

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