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The Analysis of Sound Attributes on Sensibility Dimensions*

소리의 청각적 속성에 따른 감성차원 분석

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Abstract : As is commonly said, music is 'language of emotions.' It is because sound is a plentiful modality to communicate the human sensibility information. However, most researches of auditory displays were focused on improving efficiency on user's performance data such as performance time and accuracy. Recently, many of researchers in auditory displays acknowledge that individual preference and sensible satisfaction may be a more important factor than the performance data. On this ground, in the present study we constructed the sound sensibility dimensions ('Pleasure', 'Complexity', and 'Activity') and systematically examined the attributes of sound on the sensibility dimensions and analyzed the meanings. As a result, sound sensibility dimensions depended on each sound attributes, and some sound attributes interact with one another. Consequently, the results of the present study will provide the useful possibilities of applying the affective influence in the field of auditory displays needing the applications of the sensibility information according to the sound attributes.

Key words : Sound attributes, sensibility dimensions, auditory display, AUI

요약 : 소리나 음악을 '감정, 감성의 언어'라고 표현한다. 이것은 소리라는 물리적 속성들이 인간의 감성 정보를 효과적이고 풍부하게 전달하는 좋은 수단일 수 있기 때문이다. 하지만 정보의 청각적 제시에 대한 효과적 방안을 연구하는 청각 디스플레이(auditory displays) 분야의 연구자들은 주로 특정 시스템 사용자의 과제수행 결과의 효율성 증진에만 초점을 맞추어 왔었다. 이러한 한계점을 극복하고 청각적 정보 제시의 적용 영역을 확장하고자 최근 많은 연구자들이 과제수행 결과뿐 아니라 개인의 선호와 감성적 만족이 더 중요한 요인이 될 수 있음을 지적하고 있다. 이런 배경으로 본 연구에서는 소리에 대한 감성어휘 수집과 분석을 통해 소리의 감성공간을 '즐거움(Pleasure)', '복잡성(Complexity)', '활동성(Activity)'의 세 개 차원으로 구축하고, 그 차원에서 음고(pitch), 음량(loudness), 음색(timbre), 그리고 지속시간(duration)과 같은 소리의 다양한 속성에 따른 감성의 이동을

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체계적으로 살펴보았다. 그 결과, 각 차원들에서 소리의 여러 속성들에 따른 감성적 차이와 그 상호관계를 확인하였다. 결론적으로 이러한 결과들은 청각 사용자 인터페이스(Auditory User Interface)와 같이 청각 디스플레이 (auditory displays) 분야에 적용되어 소리의 속성에 따라 감성 정보를 응용하여 사용자의 특성과 요구에 맞춰 정보를 제시하는 데 기여할 것이다.
주요어 : 소리 속성, 감성 차원, 청각적 정보 제시, 청각 사용자 인터페이스

1. Introduction

When we close our eyes on the street, there are plenty of sounds competing for selection by us. Even though some of them have non-speech sounds without verbal meaning such as bird's chirping or thunder, we don't doubt that we feel certain emotions to those sounds. Moreover, a number of people choose music according to a certain sensibility induced by the music to amuse them. In other words, auditory sense as sound or music is able to arouse deep and significant emotions in those who interact with it [10]. It has been examined that auditory sense as sounds or music is a far more expressible channel than other senses [1, 2, 3, 4, 6, 8, 9, 11]. Therefore, we should consider auditory display as well as visual display on the user interface for user's sensibilities.

However, there were few researches about auditory sensibility because of difficulty in methodological respects [8]. Mostly, sensibility dimension for sound wasn't regarded as an important factor when some application is designed. Instead, system designers only paid attention to improve user's performance efficiency by measuring the performance time and accuracy in an operated auditory display condition of a certain system. Nevertheless, if we can make clear which attributes are main factors in determining sensibility for sound, it can be a meaningful index to auditory display design [5]. For instance, we can apply these sensibility information to generating the sound signals as the user's feedback from various domestic appliances and use to improve user's satisfaction of systems as well as performance, such as user interfaces, websites, products, etc.

We anticipated the reason people feel particular sensibility to different sound is every sound has its own unique attributes such as pitch, loudness, timbre, and duration. On this ground, the present study aimed to investigate what determine the auditory sensibility dimensions by analyzing sound adjectives and make a chance providing valuable sensibility information for auditory displays by collecting and analyzing various sensibilities for sounds.

In this study, we would like to examine auditory sensibilities when certain properties of sound changed in the auditory sensibility dimensions. We expect that we felt different sensibility to sound if certain attributes of that sound change enough.

In consequence, through present study we hope these results could provide a significant guide to design auditory displays in the various fields relative to sound.

2. Sound Sensibility Dimensions

To apply feelings for sounds to real systems, the processes that systematize the relations between physical sounds and feelings by abstracting fundamental sensibilities for sounds and clarifying related physical properties should be preceded. Consequently, in this study we collected various sensibility adjectives explainable for sounds by diverse means, such as the free association methods and related previous sensibility studies, and abstracted feelings from sounds based on the result of rating various sensibility adjectives according to several sound stimuli. This process is grounded on the Semantic Differential method [7] used to estimate sensibilities for a concrete object owing to the difficulty of expression for sensibilities. And then, we spatially represented sensibilities expressible for sounds by analyzing adjectives rated at physical sound patterns by the Multidimensional Scaling, and derived fundamental sensibility dimensions from the distribution.

2.1 Method

2.1.1 Participants

Fifty university students with normal vision and hearing served as participants in the first survey to collect various sound sensibility adjectives. For factor analysis, twenty-five university students participated in the second survey. Finally, forty-eight university students served as participants in a validity rating for sound sensibilities. None had participated in two or more questionnaire surveys for exclusion from previous survey's interference.

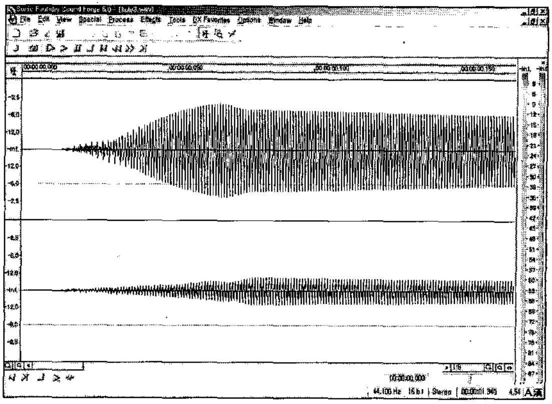

Figure 1. Image of a sound stimulus (pitch: C6, loudness: +20dB, timbre: flute) used in these studies. In this study, twenty-seven sound stimuli like above a sample were used

2.1.2 Apparatus & Stimuli

In the collecting survey, participants wrote down various sound sensibility adjectives by the free association or listening ten instrumental tones (guitar, churchorgan, clarinet, harpsichord, oboe, piano, timpani, trombone, trumpet, vibraphone, violin) on the computer program. For validity rating survey for sound sensibility adjectives, twenty-seven sounds including various timbres, pitch, and loudness each were made for the present study. They were divided into three levels each. Timbre levels consisted of string instruments (violin, viola, cello), wind instruments (flute, oboe, trombone), and piano. Their composition reflects the musical compass of each instrument. Pitch levels were composed of C2 (65.41 Hz), C4 (261.63 Hz: middle C), and C6 (1046.50 Hz). Loudness levels were also made up three steps of peak amplitude (about -20dB, -10dB, 0dB) and each step has 10dB difference. The stimuli sounds were made in Cakewalk Pro Audio 9.0 and then they were amplified differently in Sonic Foundry Sound Forge 6.0. The computer monitor was a 17

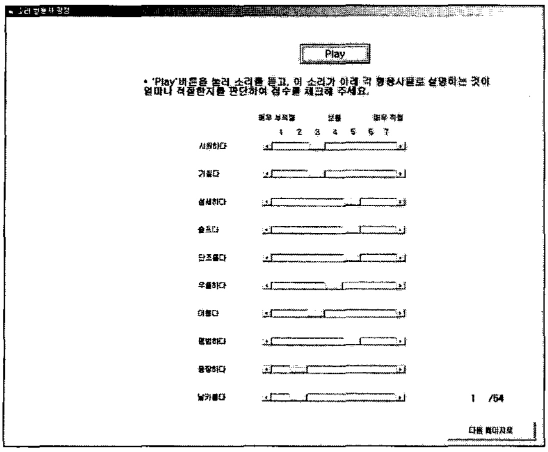

Figure 2. Image of the screen layout seen by participants in questionnaire surveys. The survey was programmed in Visual Basic 6.0

inch CRT display set to a resolution of 1024×768 pixels, with 32-bit color. The listeners wore Cosy CMC-07 headset, adjusted for fit and comfort, and used a standard two-button wheel mouse to respond. The frequency response of the headset was 8Hz~22kHz.

2.1.3 Procedure

In the collecting survey, participants reported various sound sensibility adjectives by the free association or listening ten instrumental tones. At the beginning of the validity rating survey session, participants heard a set of instructions that explained the procedure. Participants were provided with one of twenty-seven sounds, and then a seven-point Likert-type validity scale (1point: highly irrelevant, 4point: medium, 7point: highly relevant) was used to monitor the self-rated levels of 120 adjectives. Each of the participants had brought in one selection for each of adjectives how much 120 adjectives are suitable for a stimulus after a session listening to a certain sound stimulus that played randomly in the twenty-seven sounds. In the next step, the number of abstracted sensibility adjectives was twenty, only different from the previous step.

2.2 Results & Discussion

As the results of this study, we first selected adjectives rated at average five-point or more that is higher than four-point as the medium point. In addition to a validity rating for sensibility adjectives related to sound, participants reported sensibilities by the free association after listening to several sound stimuli. Consequently, sixty sound sensibility adjectives were selected through this process.

Subsequently, a factor analysis was conducted for analyzing and reducing adjectives expressible for similar sensibilities and abstracting more relevant of selected adjectives to explain sounds. In the result of the factor analysis, though selected sixty adjectives were reduced to nine sensibility factors over eigenvalue 1 related to sound experience, we selected seven factors because they were decided by scree plot and had 61.6% variance accounted for. Accordingly, we abstracted twenty fundamental sensibilities(several adjectives per factor) by analyzing sensibility adjectives representing each factor that have a high correlation in the seven factors (Table 1).

As a result of the Multidimensional Scaling (MDS), a three-dimensional model regarding sound sensibilities was suitable for modeling as Stress index is .084 and explained about 95.1% of all variation with three dimensions. Sound sensibility dimensions analyzed by MDS are shown in Figure 3 & 4.

We were aware that three types of dimensions are able to explain sound sensibility dimensions.

Table 1. Abstracted twenty sound sensibility adjectives by factor analysis

cheerful (경쾌하다)	harsh (거칠다)	dynamic (다이나믹하다)	confused (혼란스럽다)
lively (발랄하다)	uneasy (불안하다)	cool (시원하다)	scared (두렵다)
boring (지루하다)	sharp (날카롭다)	comfortable (포근하다)	gloomy (우울하다)
calm (잔잔하다)	magnificent (웅장하다)	sad (슬프다)	fine (섬세하다)
dark (어둡다)	monotonous (단조롭다)	dull (둔탁하다)	common (평범하다)

The first dimension is represented as the horizontal axis in Figure 3. In the first dimension, there is a tendency that divided sensibilities between pleasant conditional adjectives such as 'cool', 'cheerful', and 'lively' and unpleasant conditional adjectives such as 'gloomy', 'sad', and 'dark' according to a degree of pleasure. Therefore we named the first dimension 'pleasant-unpleasant.' The second dimension is represented as the vertical axis in Figure 3. Subsequently, the second dimension was called the 'complex-simple' dimension because of a division of sensibilities between complex conditional adjectives such as 'uneasy', 'confused', and 'sharp' and simple conditional adjectives such as 'comfortable', 'calm', and 'common' according to a degree of complexity. Lastly, the third dimension is shown as the depth axis in Figure 3. In the third dimension,

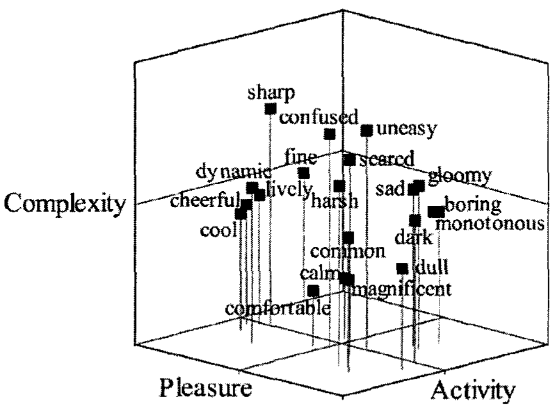

Figure 3. Results showing three sound sensibility dimensions; Pleasure, Complexity, and Activity dimensions

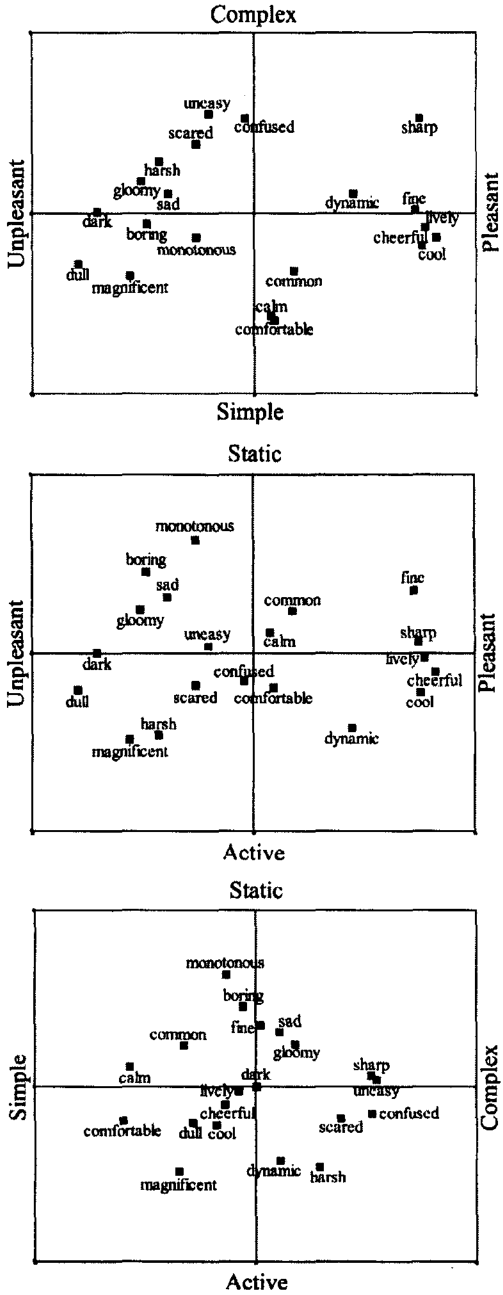

Figure 4. Results showing three pairs of two sound sensibility dimensions

there is a tendency that divided sensibilities between active conditional adjectives such as 'dynamic', 'magnificent', and 'harsh' and static conditional adjectives such as 'monotonous', 'boring', and 'fine' according to a degree of activity. Therefore we named the third dimension 'active-static.'

3. Positioning Sound Attributes on Sensibility Dimensions

To assess where sound attributes were located on sensibility dimensions, participants conducted the positioning task to locate their feelings for each sound by clicking a certain point on three sensibility dimensions. It is to investigate the change in sensibility space according to sound attributes such as pitch, loudness, timbre, and duration.

3.1 Method

3.1.1 Participants

Forty-four university students with normal vision and hearing served as participants in the positioning task to locate various sounds on three sensibility dimensions.

3.1.2 Apparatus & Stimuli

Apparatus and stimuli were the same as those used in the previous step except fifty-four sounds including two levels of play duration attribute (1,000ms, 500ms).

3.1.3 Procedure

At the beginning, participants were instructed to understand the procedure. Like Figure 5, par-

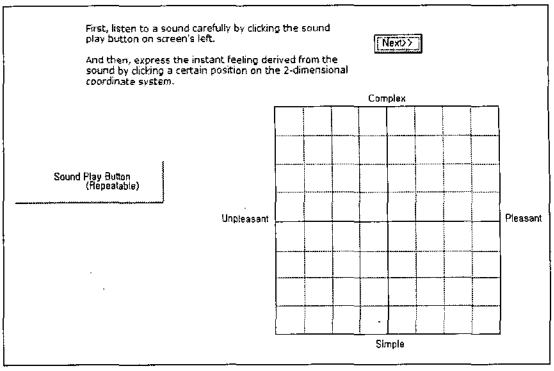

Figure 5. Image of the screen layout seen by participants in positioning sound signals on sensibility dimensions

ticipants were provided with one of fifty-four sounds, and then they located their sensibilities by clicking a certain point into mouse on the two dimension coordinates of three dimension combinations such as 'pleasure-complexity', 'pleasure-activity', and 'complexity-activity', respectively. All participants' responses were recorded in the values of X-Y coordinates.

3.2 Results & Discussion

As the result of this experiment, we compared the values of coordinates on sound sensibility dimensions respecting sound attributes.

First, pitch regarding the frequency of sound, one of the most interested sound attributes, showed the significant differences on the 'Pleasure' and 'Complexity' dimensions. The lower pitch tone (C2) is less pleasant than the higher pitch tones (C4, C6) [$F(2,86) = 102.947$, $MSe = 9.244$, $p < .01$] and more complex than the higher tones [$F(2,86) = 4.132$, $MSe = 12.101$, $p < .05$]. A low pitch tone gives us more 'gloomy' or 'sad' feelings and a little 'complex' feelings. In the 'Activity'

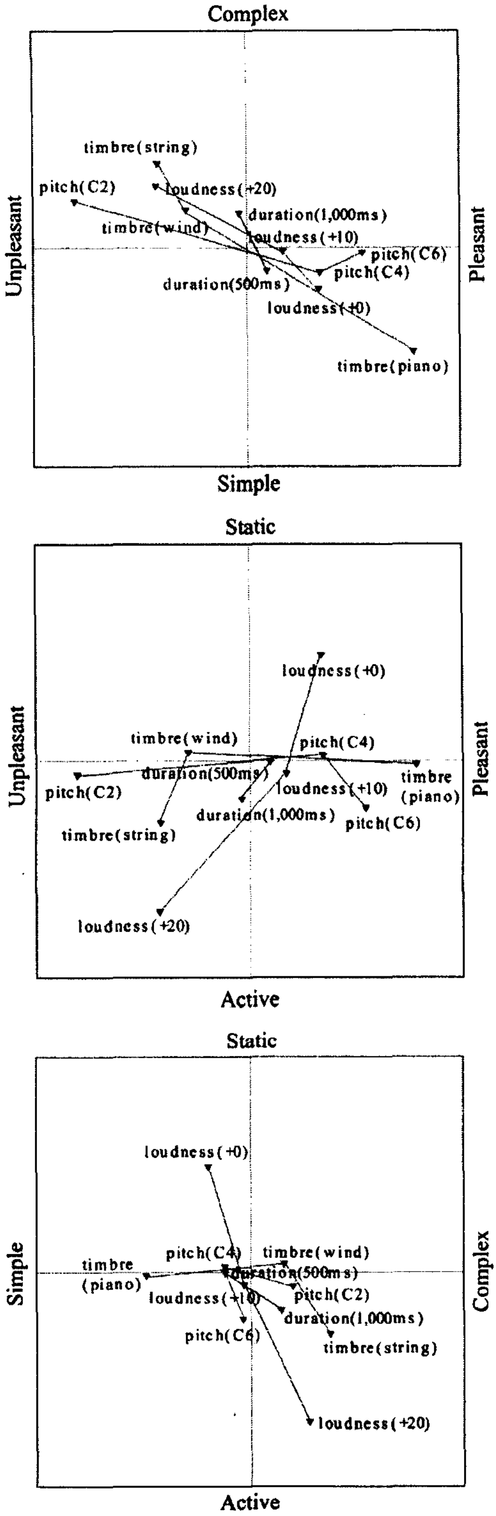

Figure 6. Results from Sound Sensibility Positioning task; various sound attributes located on three sensibility dimensions

dimension, pitch did not show any significant difference.

Loudness regarding the intensity of sound qualified all sensibility dimensions('Pleasure', 'Complexity', and 'Activity' dimensions in order) [$F(2,86) = 33.612$, $MSe = 8.472$, $p<.01$; $F(2,86) = 33.212$, $MSe = 3.050$, $p<.01$; $F(2,86) = 47.582$, $MSe = 5.910$, $p<.01$]. The louder tones were less pleasant than +0 and +10 dB tones, and the louder a tone is the more complex and active.

Timbre defined as several instrumental sounds in this study showed significant differences in the 'Pleasure' and 'Complexity' dimensions [$F(2,86) = 139.899$, $MSe = 5.526$, $p<.01$; $F(2,86) = 49.578$, $MSe = 7.254$, $p<.01$]. Piano tones were more pleasant and simpler than string and wind instrumental tones such as cello, viola, violin, flute, oboe, and trombone tones.

Finally, duration, a tone's playtime, revealed relation to pleasure and complexity on sensibility dimensions [$F(1,43) = 12.017$, $MSe = 1.839$, $p<.01$; $F(1,43) = 25.276$, $MSe = 3.640$, $p<.01$]. Tones played for 500ms were a little more pleasant and simpler than 1,000ms.

In addition to each main effect, there were several interactions. One of these interactions was between pitch and loudness in the 'Pleasure' dimension. Loudness was more affected at the low pitch, that is, low pitch and louder tones were more unpleasant, but high pitch tones gave rise to less difference of pleasure with respect to loudness [$F(4,172) = 7.441$, $MSe = 1.739$, $p<.01$]. The second interaction was between pitch and timbre in the 'Pleasure' dimension (Figure 7). According as the pitch increases, piano tones were more pleasant than string and wind tones [$F(4,172) = 12.343$, $MSe = 2.214$, $p<.01$]. The third interaction was between loudness and timbre in the 'Pleasure' dimension. According as the loudness increases, string tones were more unpleasant than piano and wind tones [F(4,172) = 10.359, MSe = 1.509, p<.01]. The forth interaction was between timbre and duration in the 'Pleasure' dimension. Piano tones weren't affected by duration, but string and wind tones were more unpleasant at the longer duration [F(2,86) = 6.007, MSe = 1.315, p<.01]. The fifth interaction was between pitch and timbre in the 'Complexity' dimension. The higher pitch string tones, the more complex, but the higher pitch piano and wind tones, the simpler [F(4,172) = 17.533, MSe = 2.249, p<.01]. The sixth interaction was between timbre and duration in the 'Complexity' dimension. Piano tones weren't affected by duration, but string and wind tones were more complex at the longer duration [F(2,86) = 10.489, MSe = 1.564, p<.01]. And the last interaction was between pitch and timbre in the 'Activity' dimension (Figure 8). According as the pitch

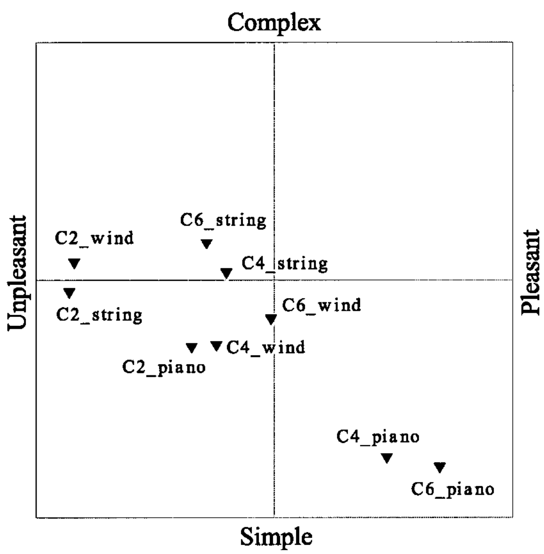

Figure 7. Results showing interaction between pitch and timbre on pleasure-complexity dimensions

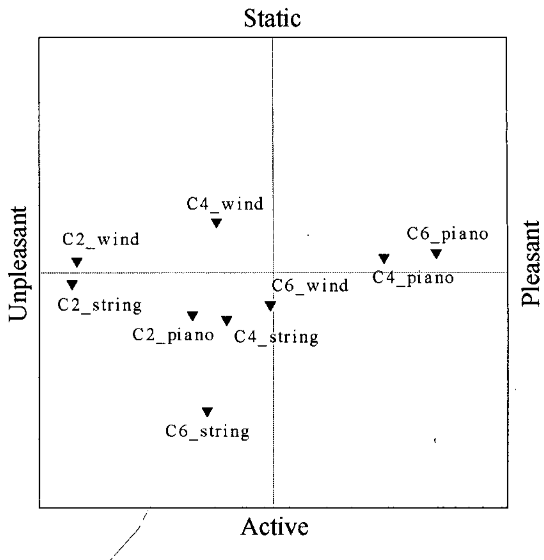

Figure 8. Results showing interaction between pitch and timbre on Pleasure-Activity dimensions

increases, piano tones were more static than string and wind tones [F(4,172) = 3.781, MSe = 3.047, p<.01]. Consequently, on the basis of these results, we can expect generally acceptable sounds occurring fine or cheerful feelings, for instance.

4. Conclusions

In sum, we ascertained sensibility dimensions for sound patterns by analyzing twenty sensibilities by MDS. Sensibilities from sound patterns could be explained in three dimensions. Sound sensibility dimensions identified from the present study seem to be related to the sensibility dimensions of adjectives proposed by Osgood et al. [7]. We investigated the change of sensibilities according to sound attributes by positioning feelings on two-dimensional spaces that stimulus sounds raised in the experiment.

In any event, we pointed out above that recent opinions that the usefulness of auditory displays in the user interface designs should be concerned about subjective feelings or satisfaction are come to the fore as well as user's task performance time or accuracy. To deal with this point pertinently, it will be indicated clearly that abstracting sound sensibility dimensions and information on what kind of character is derived from sound attributes in the dimensions are critical factors to maximize the effects of user interfaces by inducing a certain feeling through efficient auditory displays.

Conclusively, in our estimation, useful impact expected at the system design stage could be acquired if auditory displays with reference to sound sensibility dimensions appeal to user's contentment or feelings as well as the time required or errors committed in the user interface. Therefore, in further studies, we plan to develop new applications with due regard to user's sensibilities.

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