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Quantitative Estimation of Effects of Musical Parameters on Emotional Features

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ABSTRACT

It has been shown that musical emotion can be illustrated by a two-dimensional model, which is spanned by "valence" and "arousal" axes, and experimental studies has revealed the correlations between the emotional features and musical parameters. However, the quantitative correlations between the effects of different parameters on the emotional features have not been clarified, yet. The two-dimensional plane of musical emotion is illustrated by orthogonal axes of "cheerfulness" and "tension", rotating the two axes of "valence" and "arousal" in 45 degrees. In the present study, effects of several musical parameters on the "cheerfulness" and "tension" were estimated, quantitatively. In the present study, three listening experiments were conducted, using simple musical scales performed by pure tones as stimuli. In the first and second experiments, Scheffe's paired comparison method was applied. In the first experiment, scales were provided as stimuli, varying tempo, performing resister and tonality systematically, and listeners compared and rated the "cheerfulness" of measure. Using the results of the experiment, a quantitative scale CM (Cheerfulness of Music) was determined and the effects of the parameters of tempo, resister and tonality on the cheerfulness were estimated on the CM measure. In the second experiment, ascending major scales were provided as stimuli varying tempo, sound level and articulation, and listeners rated the "tension" of the scales. A quantitative measure TM (Tense of Music) was determined. In the last experiment, 15 stimuli were selected from the stimuli used in the first and second experiment, and listeners rated similarity between every pair of the stimuli. Multiple-dimensional scaling of the similarity matrix showed a three-dimensional solution. Moreover, multiple-regression analyses, using the values on the three dimensions as independent variable and the CM and TM values as dependent variables, showed that the first and second dimensions are almost along with the CM and TM measures, respectively. Then, one PU (Perceptual Unit) was determined as the perceptual difference between one CM on the cheerfulness, and TM measure was translated into PU measure. The stimuli were plotted on the cheerfulness-tension plane, and the plots successfully revealed the effects of tempo, register, tonality, sound level and articulation both on the cheerfulness and tension, quantitatively.

I. INTRODUCTION

Musical emotion is expressed in various adjectives such as cheerful, tender, majestic, tec. This implies that musical emotion is illustrated by a multi-dimensional space. Many psychologists examined how this space is constructed. Hevner (1936, 1937) arranged a large number of emotional terms in eight clusters in a simple circular configuration. She used this circular model to determine emotional features of musical materials. Russell (1980) showed that the emotion is illustrated by a circumplex model, which is spanned by "valence" and "arousal" dimensions. Russell's circumplex model showed a consistent configuration of adjectives with Hevner's clusters.

In the configuration of adjectives in Russell's and Hevner's models, another orthogonal set of emotions, "cheerfulness" and "tense" can be observed, rotating the two axes of "valence" and "arousal" in 45 degrees. This implies that the musical emotion can be interpreted as the two-dimensional plane, spanned by "cheerfulness" and "tense" axes.

It is well known that a melody played in a major key is more-cheerful than one played in a minor key. It is also known that a melody played in a high register at a rapid tempo is more cheerful than in a low register at a slow tempo. Juslin (2001) reviewed such correlations between emotional features and musical and physical parameters which constructs music, *e.g.*, tempo, sound level, articulation, spectrum. However, it has not been quantitatively defied how the parameters determine an emotional feature. For example, it has not been compared the effect of tonality (major/minor) and the effect of doubling the tempo on the perceptual cheerfulness of music.

In the present study, three listening experiments were conducted, using simple musical scales performed by pure tones as stimuli. In the first and second experiments, Scheffe's paired comparison method was applied. In the first experiment, effects of tempo, performing register and tonality on the cheerfulness was estimated and a quantitative measure of the cheerfulness was constructed. In the second experiment, effects of tempo, sound level and articulation on the tension was estimated and a quantitative measure of the tension was constructed. In the last experiment, some of the stimuli used in the first and second experiment were used as stimuli, and listeners rated similarity between every pair of the stimuli. Multiple-dimensional scaling of the similarity matrix showed the quantitative correlation between the two quantitative measures of cheerfulness and tension, and the effects of tempo, register, tonality, sound level and articulation both on the cheerfulness and tension, were revealed quantitatively

II. EXPERIMENT 1

A. Method

In the present experiment, Scheffe's paired comparison method was applied. Eight students, ranging from 21 to 24 years old, participated from the Kanazawa Institute of Technology as listeners. In the present experiment, musical scales were used as stimuli. In the present study, articulation value is determined by the ratio of duration to inter-onset interval, and the performing resister is determined by the spectral centroid of the averall-term spectrum, on the ERB-rate scale (Glasberg and Moore, 1900). In the present experiment, the articulation value was fixed at 1.0.

The present experiment was consisted of three sessions. In Session 1, five ascending measure scales with the tempo of 70.7 100, 141.4, 200, 282.8 BPM were prepared. For these five

stimuli, the spectral centroid was fixed at 15.62 ERB-rate. The centroid of 15.62 ERB-rate corresponded to 1000 Hz. An ascending major scale with the spectral centroid of 12.62 ERB-rate at 141.1 BPM was added to the five stimuli, and set of the six stimuli were used in Session 1. The listeners listened to every pair of the six stimuli through the headphones STAX Lambda-professional at the level of LAeq=83 dB. Then the listeners were requested to compare the perceptual degree of cheerfulness for the former and latter stimuli, and rate them in seven-step categories, *i.e.,* "the latter is very cheerful in comparison with the former", "the latter is fairly cheerful in comparison with the former", …, "the latter is very cheerful in comparison with the former".

In Session 2, four ascending major scales with the spectral centroid of 9.62, 12.62, 15.62, 18.62 ERB-rate were prepared. The tempo was fixed at 141.4 BPM for these four stimuli. Adding an ascending melodic minor scale, in total five scales were used as stimuli in Session 2. The other conditions and experimental procedure was identical to Session 1.

In Session 3, ascending major scale, ascending melodic minor scale, ascending natural minor scale, descending major scale, descending natural minor scale were used as stimuli. The cnetroid was fixed at 15.62 ERB-rate. The other conditions and experimental procedure were identical to Sessions 1 and 2.

The three sessions were separated by a 10-min rest period. Each listener completed all the three sessions in one day.

B. Results and Discussion

Figure 1 shows the mean value of the cheerfulness for each stimulus the listeners evaluated in Session 1. Figure 1 shows that the ascending major scale at a fast tempo sounds more cheerful than a slow tempo. Figure 2 shows the results in Session 2. Figure 2 shows that the scale with a high spectral centroid sounds cheerful than with a low centroid. Figure 3 shows the results in Session. In Fig. 3, the cheerfulness decreases in the following order: ascending major scale, ascending melodic minor scale, descending natural minor scale, ascending natural minor scale, and descending major scale.

Session 1 and Session 2 included two common stimuli; the ascending major scale with the centroid of 12.62 ERB-rate at 141.4 BPM and the scale with the centroid of 15.62 ERB-rate at 141.4 BPM. Session 2 and 3 included two common stimuli; the ascending major scale and ascending melodic minor scale. The three scales shown in Figs. 1-3 are independent interval scales. However, the intervals of the cheerfulness between the same pairs of the stimuli must be the same. Moreover, Fig. 2 shows that increasing the centroid in 3 ERB-rate increases the cheerfulness in equal perceptual interval. Using these results, we defined the musical cheerfulness of a given scale as "the ERB-rate of the centroid for the overall-term spectrum of the ascending major scale played by pure tones at the tempo of 141.4 BPM, which are perceived as cheerful," and call this measure CM (Cheerfulness of Music). In Fig. 4, the stimuli used in Session 1 and 3 are marked on the CM measure. Figure 4 reveals the quantitative correlation among the effects of the parameters on the cheerfulness as follows: doubling the tempo increases the degree of cheerfulness in 3 CM. The ascending major scale is more cheerful than the ascending melodic minor scale in 1.5 CM. The ascending melodic minor scale is more cheerful than the ascending natural minor scale in 1.0 CM.

III. EXPERIMENT 2

A. Method

In the present experiment, Scheffe's paired comparison method was applied, again. Eight students, who were identical to Experiment 1 participated as listeners. In the present experiment, the ascending scales performed by pure tones were used as stimuli. In the present study, spectral centroid was fixed at 15.62 ERB-rate.

The present experiment was consisted of three sessions, again. In Session 1, five ascending measure scales with the tempo of 70.7 100, 141.4, 200, 282.8 BPM were used. For these five stimuli, the articulation value was fixed at 1.0 and the sound level was fixed at LAeq=85 dB. These stimuli were used also in Session 1 of Experiment 1. Every pair of the five stimuli were presented through the headphones. The listeners compare the perceptual degree of tension for the former and latter stimuli, and rate them in seven-step categories,

In Session 2, four stimuli the sound level of 89, 83, 77, 71 dB were prepared. For these stimuli, tempo was fixed at 141.4 BPM. Adding the 83 dB stimulus at 141.4 BPM, in total five stimuli were used in Session 2. The other conditions and the experimental procedure were identical to Session 1.

In Session 3, the stimuli with the articulation value of 1.0, 0.75, 0.5, 0.25 were prepared. The stimulus with the articulation value of 1.0 sounded legato and the stimulus with the articulation value of 0.25 sounded staccato. Adding the stimulus with the articulation value of 1.0 at 282.8 BPM, five stimuli were used in Session 3. The other conditions and the experimental procedure were identical to Session 1 and 2.

B. Results and Discussion

The perceptual scales of tense were constructed for Session 1-3. The sets of stimuli in the three sessions consistently included two common stimuli: the stimulus with the articulation value of 1.0 at 141.1 BPM presented at 83 dB and the stimulus with the articulation value of 1.0 at 282.9 BPM presented at 83 dB. Using the correlation that the distance between the two common stimuli on the tension must be equal interval, the TM (Tense of Music) was defined as follows: The tense of the stimulus with the articulation value of 1.0 at 141.4 dB presented at 83 dB is set at 2.0 TM. Then the tense of the stimulus with the articulation value of 1.0 at 282.8 BPM presented at 84 dB set at 3.0 TM. Then the tense of the other stimuli are plotted on the TM measure along with the interval scales of the results of Session 1-3. Figure 5 shows the TM measure. Figure 5 reveals the correlation among the effects of the parameters on tense as follows: A 6-dB increase in sound level increases the tense in 1 TM. Decrease the articulation value from 1.0 to 0.25 increases the degree of tense in 1.0 TM, also increases the degree of tense in 1.0 TM.

IV. EXPERIMENT 3

A. Method

In the present experiment, multiple-dimensional scaling was applied. Three students and one professor participated as listeners. The listeners had experience as professional or amateur musicians. For the present experiment, 15 stimuli used in Experiment 1 and 2 were prepared excluding the stimuli at the tempi of 100 and 200 BPM.

The listeners listened to every pair of the 15 stimuli through the headphones, and then rated the dissimilarity between the two stimuli using a seven-step scale.

B. Results and Discussion

One of the programs for multi-dimensional scaling, PROXSXAL was used to analyse the dissimilarity matrix. The results showed that the stress value for a three-dimensional solution was 0.057. Multiple-regression analyses, using the values on the three dimensions as independent variable and the CM and TM values as dependent variables, showed that the first and second dimensions are almost along with the CM and TM measures, respectively. Then, one PU (Perceptual Unit) was determined as the perceptual difference between one CM on the cheerfulness, and TM measure was translated into PU measure. Figure 6 shows the two dimensions which correspond to the cheerfulness and tense. In Fig. 6, the 15 stimuli are plotted on the cheerfulness-tension plane. Fig. 6 revealed the effects of parameters on the emotional features quantitatively: An increase of spectral centroid in 1 ERB-rate increases the degree of cheerfulness in 1.0 PU and decreases the degree of tension in 0.2 PU. An increase of sound level in 6 dB decreases the cheerfulness in 0.3 PU and increases the tense in 1.4 PU. Doubling the tempo increases the cheerfulness in 3.2 PU and increases the tense in 1.0 PU.

V. CONCLUSIONS

In the present experiment, Scheffe's paired comparison method and multi-dimensional scaling were applied to the attempt of quantitative estimation of the effects of several parameters of music on the emotional features.

In the present study, a small number of listener listened to very simple stimuli of musical scales. More complex and long sequence of tones has to be evaluated by a large number of listeners, in the next step.

ACKNOWLEDGMENT

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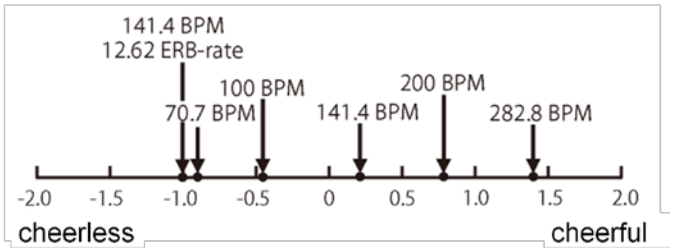

Fig. 1 Results in Session 1, Experiment 1. The stimuli, which are not labeled by centroid values, possessed 15.62 ERB-rate in the centroid.

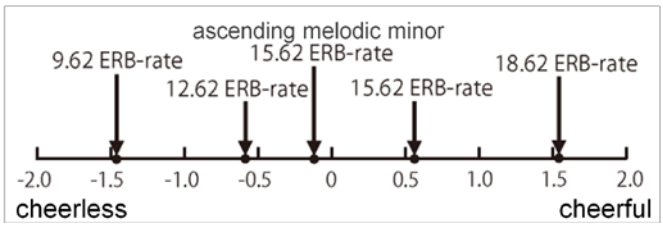

Fig. 2 Results in Session 2, Experiment 1. The stimuli, which are not labelled by a tonality, played the ascending major scales

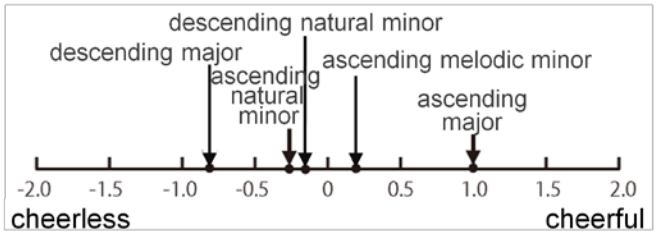

Fig. 3 Results in Session 3, Experiment 1

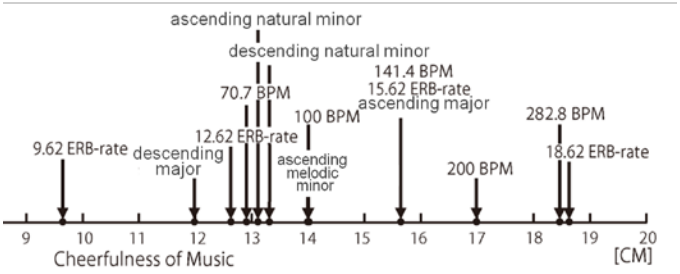

Fig. 4 The stimuli used in Session 1 and 3, Experiment 1 are plotted on the CM (Cheerfulness of Music) measure. The stimuli without centroid labels, possessed the 15.62 ERB-rate in the centroid, and the stimuli without tempo labels are played at 141.4 BPM

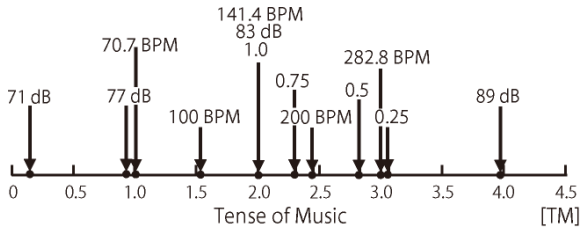

Fig. 5 The stimuli used in Experiment 2 are plotted on the TM (Tense of Music) measure. The stimuli without tempo labels played at 141.4 BPM, and the stimuli without sound level labels are presented al LAeq=83 dB.

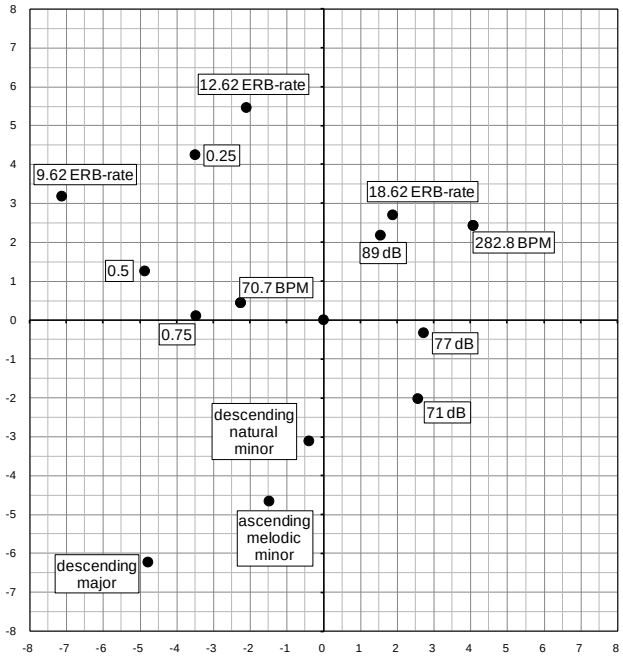

Fig. 6 The stimuli in Experiment 3 are plotted on the emotional plane. The horizontal and vertical axes show cheerfulness and tense factors. The stimulus on the origin point shows the ascending major scale played at 141.4 BPM with the centroid of 15.62 ERB-rate and the articulation value of 1.0, presented at 83 dB. One unit in the figure corresponds to 1.0 PU.