

Quantitative Estimation for the Effects of Tempo, Sound Level and Articulation on the Perceptual Tension of Music

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ABSTRACT

Several researchers have illustrated musical emotion by using two-dimensional models. These models suggest that the space of musical emotion is spanned by valence and arousal dimensions, or, cheerfulness and tension dimensions. In the present study, a perceptual experiment was conducted to estimate the effects of tempo, sound level and articulation (staccato-legato) on the perceptual degree of tension. The ascending major scale played by pure tones was used as stimuli. The performing register was fixed as possessing the overall term spectral centroid at 15.62 ERB-rate. The articulation value was defined as the duration of each tone divided by the inter-onset interval. The experiment consisted of three sessions. In Session 1, the stimuli with a variation in tempo were provided and Scheffé's paired comparison method was applied for the stimuli. In Session 2, the sound level was varied. In Session 3, the articulation value was varied. The results of the three sessions revealed the effects of tempo, sound level and articulation on the perceptual tension of music, quantitatively.

1. INTRODUCTION

Musical emotion is expressed in various adjectives such as cheerful, tender, majestic, etc. This implies that musical emotion is illustrated by a multi-dimensional space. Many psychologists examined how this space is constructed. Hevner arranged a large number of emotional terms in eight clusters in a simple circular configuration [1, 2]. This type of simple circumplex model of emotion was also presented by Russell [3]. The two-dimensional space is spanned by "valence" and "arousal level" factors. However, we can also observe an orthogonal set of emotions, "cheerfulness" and "tension" in the space. This implies that the musical emotion can be interpreted as the two-dimensional space, spanned by "cheerfulness" and "tense".

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 slow tempo. Juslin reviewed such correlations between emotional features and musical and physical parameters which constructs music, e.g., tempo, sound level, articulation, timbre [4]. However, it has not been quantitatively defined 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.

Therefore, the authors' group provided musical stimuli of major and minor scales, and played them with pure tones in various register, at various tempi, in our previous study. Using these stimuli, we conducted perceptual experiments to define the effects of tonality, tempo, and register on the cheerfulness of music, quantitatively. In this study, the performing register was defined by spectral centroid of overall term spectrum and measured in ERB-rate. The results

showed that the effect of tonality (major/minor) on the cheerfulness corresponds to centroid shift of 4 ERB-rate, and doubling the tempo corresponds to the increase of the centroid in 3.5 ERB-rate [5].

In the present study, we concentrate on the emotional dimension of "tension", which is orthogonal to the "cheerfulness" axis. We provided the ascending major scale played by pure tones and varied the three factors; tempo, sound level and articulation (staccato-legato). In the present study, the articulation value was defined as the duration of each tone divided by the inter-onset interval. Using these sound stimuli, a perceptual experiment was conducted to determine the effects of these three factors on the perceptual tension, quantitatively.

2. EXPERIMENTAL METHOD

The ascending major scale played by pure tones was provided. The performing register was fixed as possessing the overall term spectral centroid at 15.62 ERB-rate. Twenty-one students from the Kanazawa Institute of Technology participated as listeners. The experiment consisted of three sessions.

In Session 1, the sound level was fixed at 83 dB (LAeq) and the articulation value was fixed at 1.0. The tempo was set at 70.7, 100.0, 141.4, 200.0, 282.9 and 400 BPM, respectively. Scheffé's paired comparison method was applied for the stimuli: The six stimuli were paired and presented to the listeners. The listeners were requested to compare the perceptual degrees of tension for the former and latter stimuli, and rate them in seven-step categories, i.e., "the latter is very tense in comparison with the former," "the latter is fairly tense in comparison with the former," ..., "the latter is very tense in comparison with the former."

In Session 2, the sound level was set at 71, 77, 83, 89 and 95 dB respectively, with the tempo of 141.4 BPM. In addition to them, a stimulus which played in 282.9 BPM at 83 dB was used. The articulation value was fixed at 1.0 for the six stimuli.

In Session 3, the articulation value varied from 0.2 to 1.0, in steps of 0.2. For these five stimuli, the tempo was fixed at 141.4 BPM. A stimulus with 282.9 BPM and the articulation value of 1.0 was also used. The sound level was fixed at 83 dB for the six stimuli.

The 21 listeners were divided into three groups of seven listeners. Listeners in Group A participated in session 1 first, then in session 2 and 3. Listeners in Group B participated in session 2, then 3 and 1; and Group C participated in the order of session 3, 1 then 2. The experiments were separated by a 10-minute rest period and each listener completed all three experiments in one day.

3. RESULTS AND DISCUSSION

Figure 1 shows the mean value of the tense for each stimulus the listeners evaluated in Session 1. Figure 1 shows that the ascending major scale at a fast tempo sounds tenser than a slow tempo. Figure 2 shows the results in Session 2. Figure 2 shows that the scale with more intensive level sounds tenser. Figure 3 shows the results in Session 3. In Fig. 3, it is shown that the scale with a small articulation value (staccato) sounds tenser than with a large articulation value (legato).

A regression analysis was performed for the results in Session 1. The results showed that the degree of perceptual tense was almost proportional to logarithmic value of tempo shown in BPM. We defined the perceptual tense of music (TM) as follows:

$$TM = -9.030 \times \log_{10} BPM + 4.057. \quad (1)$$

Each session included two identical stimuli, which are played at 141.4 and 282.9 BPM respectively, both at 83 dB with the articulation value of 1.0. Using the psychological distance between the two stimuli in the tension, all stimuli used in the

three sessions were plotted on the TM scale quantitatively, as shown in Fig. 4.

Let the ascending major scale played with the articulation value of 1.0, at the tempo of 141.1 MPB, presented in 83 dB, as the reference stimulus. Figure 4 shows that the increase of sound level in 6 dB from the reference stimulus results in the increase of the tense in 0.45 TM. This effect is almost equal to the effect of decrease the articulation value from 1.0 to 0.4. 0.45 TM corresponds to the effect to 2.5 times the speed in BMP value, approximately.

4. CONCLUSIONS

In the present study, the effects of tempo, sound level and articulation on the perceptual tense of music, quantitatively, and constructed the metrical TM scale.

Combining the results in the present study and the results on the perceptual cheerfulness of music, we will construct a metrical space of musical emotion, where how the decrease of increase of each factor (e.g. tempo, sound level, and centroid) varies the emotional feature of music, quantitatively, in the next step.

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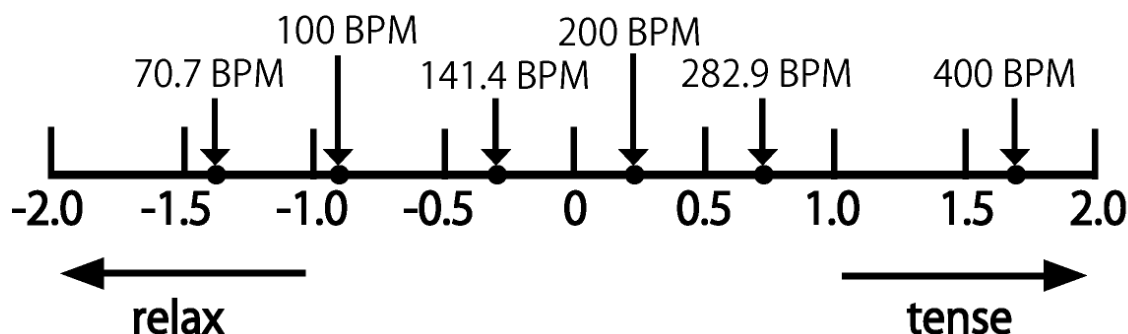


Figure 1. Results in Session 1. The ascending major scale with the centroid of 15.62 ERB-rate is played in various tempi.

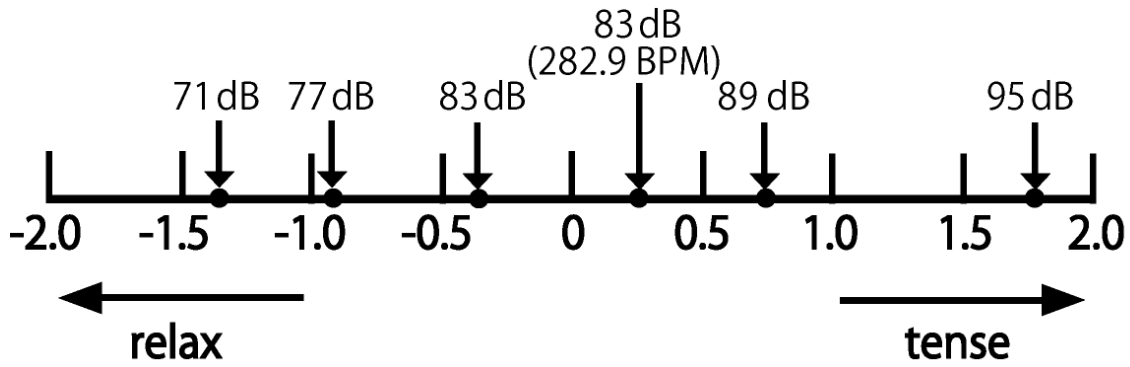


Figure 2. Results in Session 2. The ascending major scale with the centroid of 15.62 ERB-rate is presented in various sound levels, except for the stimulus which indicates "282.9 BPM" that plays at the tempo of 282.9 BPM with the sound level at 83 dB.

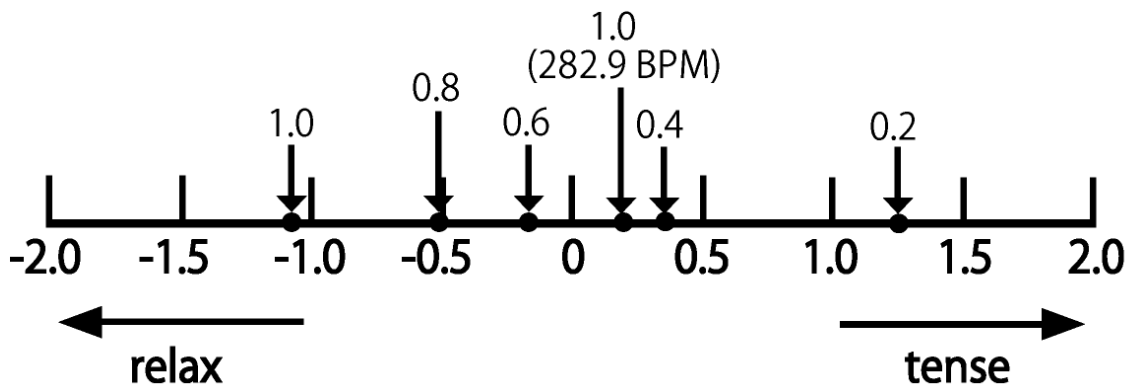


Figure 3. Results in Session 3. The ascending major scale with the centroid of 15.62 ERB-rate is played with various articulation values, except for the stimulus which indicates "282.9 BPM" that plays the speed with the 282.9 BPM with the articulation value of 1.0.

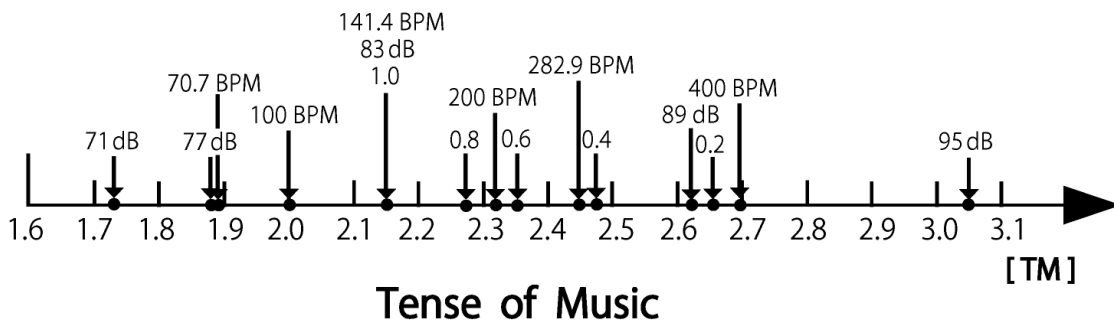


Figure 4. Stimuli used in Session 1 to 3 are marked on the TM (Tense of Music) scale.