Emotion-related Changes in Heart Rate and Its Variability during Performance and Perception of Music

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The present study investigated the differential effects of emotions evoked by music on heart rate (HR) and its variability (HRV) during the playing of music on the piano compared to those in persons listening to the same music. Thirteen elite pianists underwent experiments under expressive piano playing, nonexpressive piano playing, expressive listening, and nonexpressive listening conditions. The expressive conditions produced significantly higher levels of HR and low-frequency component of HRV, as well as a lower level of its high-frequency component. A greater modulation of these was also revealed for performance than perception. The findings suggested that musical performance would lead to a greater effect of emotion-related modulation in cardiac autonomic nerve activity than musical perception.

Key words: **emotions; expressiveness, performance; perception; heart rate variability**

Introduction

Music is commonly enjoyed by means of performance and perception. Changes in emotions with such enjoyment commonly reflect activities of the autonomic nervous system, which can be monitored by some physiological measures such as heart rate (HR) and its variability (HRV), perspiration, and respiration. Over the years, many researchers have reported modulations in these measures during musical perception.[1–7] However, there are virtually no reports of these measures during musical performance. This is surprising because from a psycho-neurophysiologic point of view, information on musical performance is equally or even more valuable than musical perception. One fundamental question is whether the emotion-related responses of HR and HRV to musical performance are the same as those of musical perception. Musical performance differs from musical perception in its involvement of a voluntary motor action that allows the performers to produce their most favorable artistic expression as well as feelings of the sound of self-generated music. It is therefore logical to hypothesize that the level of emotions attainable with musical performance will be higher, and the corresponding modulations in HR and HRV will be greater, compared to those with musical perception. This hypothesis was examined in the present study using elite pianists while they played as well as while they listened to the same single piece of music with and without emotions.

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Methods

Thirteen active classic pianists (10 females and 3 males; 22–32 years of age) played the "Well-Tempered Clavier" (Vol. I, No.1 prelude by J. S. Bach) on the piano at 60 bpm at *mezzo-forte*, and listened to the same music recorded in earlier session for each subject. This music consisted of 35 bars (four quarter-notes per bar). Experimental tasks were (1) to play this music expressively (the expressive-performance task), (2) to play the same music without emotions (the nonexpressive-performance task), (3) to listen to their own expressive-performance music with emotions (the expressive-perception task), and (4) to listen to their own nonexpressive-performance music (the nonexpressive-perception task). For these nonexpressive tasks, the subjects were instructed to voluntarily ignore any emotional responses to the music stimuli. After 5 min of seat resting, each task was performed twice in succession for another 5 min. By means of a sound-level meter, the level of sound pressure at the subject's ears was equalized between the performance and perception tasks. All subjects were trained to perform the music without viewing the score. They were also instructed to control emotion-related ancillary movements of the trunk, head, and arm to a minimum so that the level of physical activity during the expressive performance could be similar to that during the nonexpressive performance. The subjects also practiced a constant respiration rate of 15 times per minute to reduce its effect on HRV data.

Using a three-lead electrocardiogram, we collected HR data at the sampling frequency of 1 kHz for the resting and task period, and they were translated into beats-per-minute data for each R-R interval. Using the frequency-domain method, the areas of the power spectrum were computed for low-frequency (LF, 0.04–0.15 Hz), high-frequency (HF, 0.15–0.40 Hz), and total frequency (TF, 0.01–0.40 Hz) bands. The values of HF/TF and LF/HF were further obtained as indices of vagal and sympathetic nerve activities, respectively.[8] A subjective evaluation of the task was also performed using a 10-point rating scale to assess the levels of valence (1 = very unpleasant and 10 = very pleasant) and arousal (1 = lowest arousal and 10 = highest arousal) after each task. The subjects were also asked to report the portion or bars where the highest pleasant emotions were perceived.

The effects of task (perception versus performance) and expressiveness (with and without emotions) on each variable examined were statistically tested using two-way ANOVA with repeated measures, while statistical significance was accepted at $P < 0.05$.

Results

Subjective Measures

All subjects reported that they successfully differentiated the expressive tasks from the nonexpressive tasks. The expressive tasks thus had clearly higher levels of valence and arousal than the nonexpressive tasks (Table 1). Performance also provided them with a higher level of valence and arousal than listening, indicating that performance was more effective in emotion induction (Table 1). The subjects most commonly reported that the highest pleasant feeling occurred at the 28th and 30th bars (see the marks in Fig. 1), where modulations in harmonic progression occurred.

Heart Rate and Its Variability

Figure 1 shows changes in HR for all subjects for all tasks during the 1-min preparatory seat-rest period followed by the 5-min of the experimental task period. The expressive performance produced a constantly higher HR than obtained with the other tasks, and the nonexpressive perception constantly produced the lowest HR. HR for the expressive performance commonly peaked during the period of the reported highest pleasant feeling,

TABLE 1. Five-Minute Data for HR, HRV, and Subjective Evaluation Measures

Task / Emotion	Performance		Perception		ANOVA *F*-values		
	Nonexpressive	Expressive	Nonexpressive	Expressive	Task × Emotion	Task	Emotion
Arousal level	1.8 ± 1.1	3.6 ± 1.5	1.7 ± 0.9	2.6 ± 1.4	2.4	5.2*	32.3***
Valence level	4.2 ± 2.0	8.8 ± 0.9	2.9 ± 1.8	8.0 ± 1.3	0.8	9.8**	84.3***
HR (beats/min)	82.4 ± 6.4	87.8 ± 7.6	77.2 ± 5.4	78.8 ± 5.9	12.2**	17.4**	27.1***
HF/TF	22.3 ± 3.7	17.4 ± 2.8	25.0 ± 3.5	23.0 ± 3.2	15.1**	8.6*	71.1***
LF/HF	3.7 ± 0.7	4.9 ± 1.0	3.1 ± 0.6	3.4 ± 0.6	34.5***	12.0**	45.5***

The values are the mean and standard deviations for all subjects.
$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

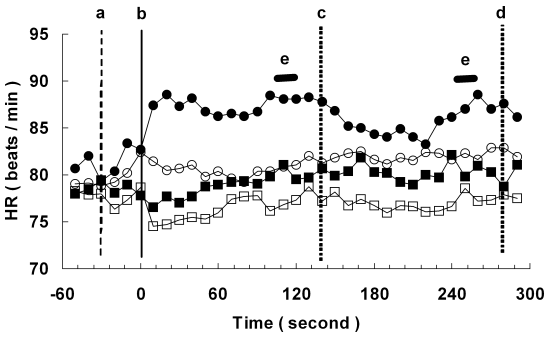

Figure 1. Time course of the 10-s mean value of HR during the pre- and experimental task period for all experimental conditions. •, expressive performance; ○, nonexpressive performance; ■, expressive perception; □, nonexpressive perception; **a**, a call for the 30 s before the task onset; **b**, the task onset moment; **c**, the end of the first round of music; **d**, the end of the second round of music; **e**, the duration for the most frequent response of highest emotions.

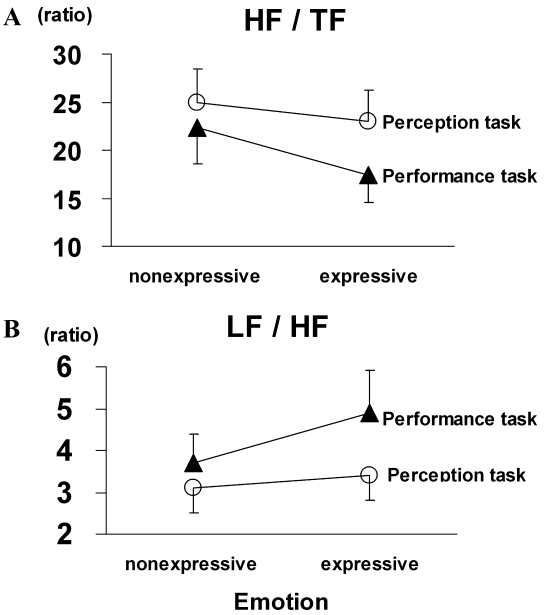

Figure 2. The mean values of HF/TF (**A**) and LF/HF (**B**) for all subjects for each task. The vertical bar indicates the SD value.

and it also had a clear gradual increase before reaching the peak, most likely reflecting anticipatory facilitation of autonomic function. The mean value of the HR, and the ratios of HF/TF and LF/HF for all subjects for each task are shown in Table 1. In all of these parameters, the effects of task and emotion, as well as their interaction were all significant (see ANOVA results in Table 1 and Fig. 2), indicating stronger emotion-induced sympathetic facilitation and vagal-tone withdrawal during musical performance than during perception.

Conclusions

Musical performance can provide a stronger effect of emotion-linked modulation in HR and its variability than musical perception in pianists. Reciprocal modulation of sympathetic and parasympathetic nervous activities is involved in this effect.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Blood, A.J. & R.J. Zatorre. 2001. Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proc. Natl. Acad. Sci. USA* **98:** 11818–11823.
2. Etzel, J.A., E.L. Johnsen, J. Dickerson, *et al*. 2006. Cardiovascular and respiratory responses during musical mood induction. *Int. J. Psychophysiol.* **61:** 57–69.
3. Krumhansl, C.L. 1997. An exploratory study of musical emotions and psychophysiology. *Can. J. Exp. Psychol.* **51:** 336–353.
4. Sammler, D., M. Grigutsch, T. Fritz, *et al*. 2007 Music and emotion: electrophysiological correlates of the processing of pleasant and unpleasant music. *Psychophysiology* **44:** 293–304.
5. Bernardi, L., C. Porta & P. Sleight. 2006. Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. *Heart* **92:** 445–452.
6. Iwanaga, M., A. Kobayashi & C. Kawasaki. 2005. Heart rate variability with repetitive exposure to music. *Biol. Psychol.* **70:** 61–66.
7. Khalfa, S., P. Isabelle, B. Jean-Pierre, *et al*. 2002. Event-related skin conductance responses to musical emotions in humans. *Neurosci. Lett.* **328:** 145–149.
8. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. 1996. Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation* **93:** 1043–1065.