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PSYCHO-CIRCULATORY RESPONSES CAUSED BY LISTENING TO MUSIC, AND EXPOSURE TO FLUCTUATING NOISE OR STEADY NOISE

H. Sakamoto

Mie Occupational Health Promotion Centre, Higashi-marunouchi 33-1, 514-0028, *Tsu city, Mie, Prefecture, Japan, E-mail: sanpo24@mx5.mesh.ne.jp*

AND

F. Hayashi, S. Sugiura and M. Tsujikawa

Mie Prefectural College of Nursing, Tsu City, Mie Prefecture, Japan

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This study investigated the effect of steady noise, fluctuating noise and music on circulatory function. Pulse-wave and blood pressure were continuously measured in 35 healthy young females who listened to three types of music or were exposed to steady noise or fluctuating noise, synchronized with each type of music with respect to intensity variations. The pulse-wave did not change during any exposure conditions. Regarding blood pressure, several modes were observed. The critical level for a blood pressure change was estimated to be $54L_{Aeq}$ during exposure to steady noise. The frequency of high-intensity peaks in the mode of sound fluctuation was associated with elevation in blood pressure. The blood pressure change was analyzed by distinguishing the intensity variation in sound fluctuation from other attributes of music. The effects of music on blood pressure were modified not only by the melody and timbre of the music but also by emotional responses during listing.

1. INTRODUCTION

We previously reported that blood pressure is significantly increased by listening to certain sounds in daily life [1]. However, the sound intensities and sound characteristics that affect circulatory functions have not been sufficiently elucidated. The present study investigated the effects on circulatory functions caused by steady noise, fluctuating noise and music. The fluctuating noise was synchronized to the intensity variations of music.

2. METHODS

The subjects were 35 healthy young females. The steady noise was a wide octave band. The music included three different types. The fluctuating noises were synchronized with each type of music with regard to intensity variations.

The profiles of the three types of music were as follows. Music E was a piece of classical music, "Eine Kleine Nacht Musik", by Mozart. Music R was a piece of popular music entitled "Star Dust", composed by Carmichael, and Music S was an arrangement made for medical and health use. To match the listening durations, the subjects listened to the first part of each music type for 130 s.

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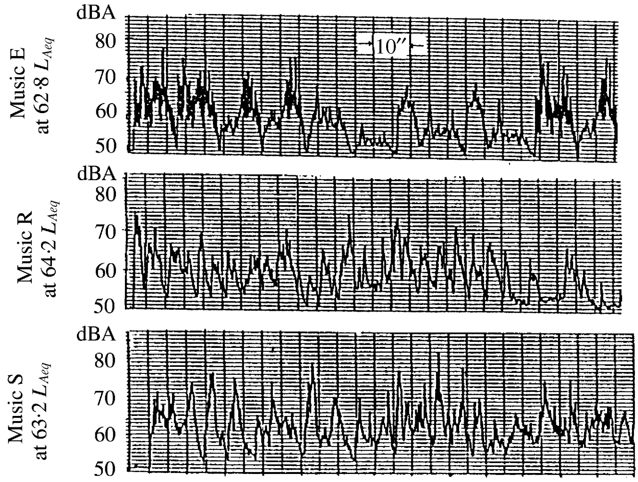

Figure 1. Sound intensity levels over time (music = fluctuating noise).

The modes of fluctuation in the sound intensity level are shown in Figure 1. The time course of intensity variations in fluctuating noise was synchronized with that in the music.

The experiment was conducted in three steps, the first being to measure the most comfortable level (MCL). Secondly, circulatory functions were recorded. The last step was to calculate the physiological index from the record. MCLs differed according to the music and a wide range was observed among individuals. Since the MCLs differed according to the music and individuals, the following three experimental series were established. In the first series, the subjects listened to Music E and were exposed to steady noise or fluctuating noise synchronized with Music E at an intensity level with the same L_{Aeq} as Music E. In the second experimental series, the subjects listened to Music R and were exposed to steady noise or fluctuating noise synchronized with Music R at an intensity level with the same L_{Aeq} as Music R. In the third experimental series, the subjects listened to Music S and were exposed to steady noise or fluctuating noise synchronized with Music S at an intensity level with the same L_{Aeq}. The order of music or noise presentation was assigned randomly.

The experimental procedure was as follows. Thirty minutes prior to the experiment, the subject was admitted to the experimental room and assumed a bed rest posture. After about 10 min, the subject was given headphones and the sensor that measured pulse-wave and blood pressure. The physiological measurements were started within 5 min of beginning to listen or the beginning of the noise exposure. Each subject listened to music and was exposed to both types of noise for 130 s. Immediately after listening to music, a self-administered questionnaire was completed to assess emotional responses. The questionnaire consisted of a comfort/discomfort measure using a five-point scale.

The pulse-wave was continuously recorded by plethysmography and the wave height and wave interval were measured. Blood pressure was continuously monitored using Finapres, and systolic and diastolic pressures were measured.

Measurements were taken twice, once 30 s before listening to music or given noise exposure, and again in the final 30 s of listening or exposure. The ratio was used as an index for the change.

A blood pressure response was defined as an increase or decrease in average pressure by more than 6% during the final stage of steady noise exposure as compared to the pressure at the pre-exposure stage.

TABLE 1

Incidence (%) of blood pressure change by exposed intensity to the steady noise

L_{Aeq}	Elevated		Decreased	
	Systolic	Diastolic	Systolic	Diastolic
–53·9	0·0	0·0	15·4‡	21·7‡
54·0–57·9	26·7†	17·1‡	6·6	5·7
58·0–	42·9†	32·6†	0·0	6·5

†$p < 0.001$, difference from 0·00%.
‡$p < 0.01$, difference from 0·00%.

TABLE 2

Incidence (%) of blood pressure change by exposed intensity to the fluctuating noise

L_{Aeq}	Elevated		Decreased	
	Systolic	Diastolic	Systolic	Diastolic
–53·9	13·3	11·5	0·3	11·5
54·0–57·9	25·9†	13·8	0·0	0·4
58·0–	21·6†	17·3†	0·4	0·8

†$p < 0.01$, difference from 0·00%.

3. RESULTS

Several modes of changes in blood pressure were observed. There was an increase in systolic and diastolic blood pressure during exposure to steady noise.

Table 1 demonstrates that, during exposure to steady noise, the incidence of elevated blood pressure was significantly increased at an intensity above $54L_{Aeq}$ dB, while the incidence of decreased blood pressure increased significantly at an intensity under $54L_{Aeq}$ dB.

There was no relationship between the blood pressure change after steady and fluctuating noise exposure. Similar results were observed in systolic and diastolic pressures and in all three experimental sessions.

Table 2 shows the results from the fluctuating noise exposure. The incidence of elevated blood pressure increased significantly at an intensity above $54L_{Aeq}$ dB for the systolic pressure and $58L_{Aeq}$ dB for diastolic pressure, while the incidence of decreased blood pressure was not significantly affected by the intensity.

The changes in blood pressure index are shown in Figure 2 in comparisons of exposure to steady noise or fluctuating noise in each experimental series. In the first and second experiments, the elevation in blood pressure was greater following exposure to steady noise than it was after exposure to fluctuating noise. In the third experiment, however, the elevation in blood pressure was greater after exposure to fluctuating noise than after exposure to steady noise. The frequencies of high-intensity peaks in the mode of sound fluctuation in the third experiment were larger than those in the first and second experiments.

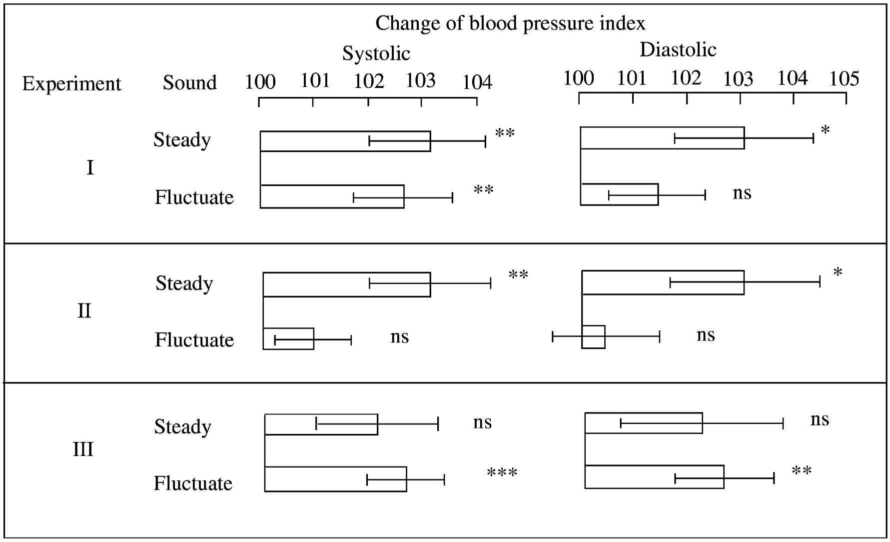

Figure 2. Change in blood pressure by exposure to steady or fluctuating noise—difference from pre-listening level (= 100) *$p < 0{\cdot}05$, **$p < 0{\cdot}01$, ***$p < 0{\cdot}001$.

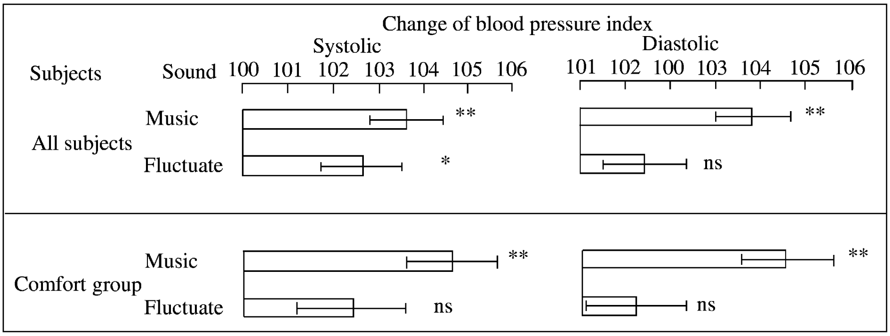

Figure 3. Blood pressure change caused by listening to music or exposure to fluctuating noise in the first experiment series—difference from pre-listening level (= 100) *$p < 0{\cdot}05$, **$p < 0{\cdot}001$.

Accordingly, the frequencies of high-intensity peaks were associated with elevations in blood pressure.

Figure 3 shows the blood pressure index comparing listening to Music E and exposure to fluctuating noise in the first experiment. The elevation in blood pressure was greater with music than with fluctuating noise. This tendency was marked in the emotional response comfort group.

Figure 4 shows the index of the blood pressure change in a comparison of listening to Music R and exposure to fluctuating noise in the second experiment. An elevation in blood pressure was observed while listening to music, but no elevation occurred during exposure to fluctuating noise. However, in the comfort group of emotional response, the elevation was limited to the systolic pressure.

Figure 5 shows the index of the blood pressure change in a comparison of listening to Music S and exposure to fluctuating noise in the third experiment. In all subjects, systolic and diastolic pressures were elevated while listening to Music S and during exposure to

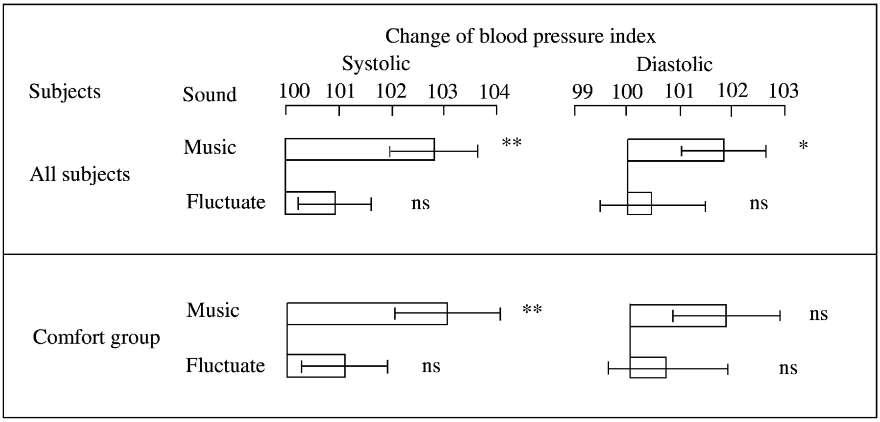

Figure 4. Blood pressure change caused by listening to music or exposure to fluctuating noise in the second experiment series—difference from pre-listening level (= 100) $*p < 0{\cdot}05$, $**p < 0{\cdot}001$.

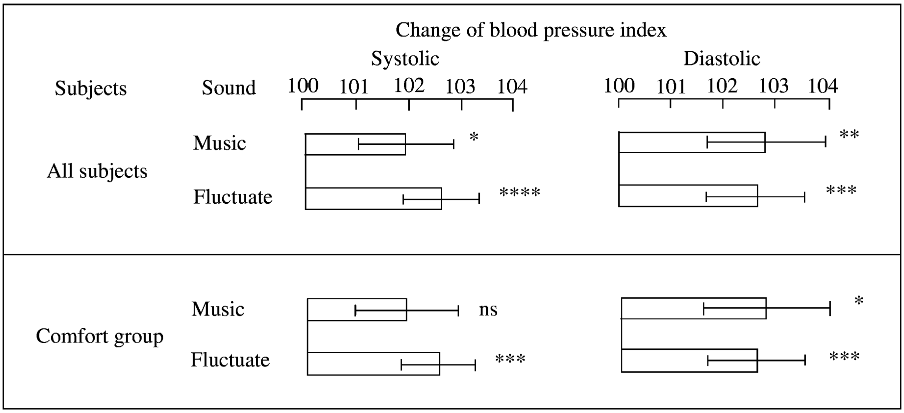

Figure 5. Blood pressure change caused by listening to music or exposure to fluctuating noise in the third experiment series—difference from pre-listening level (= 100) $*p < 0{\cdot}05$, $**p < 0{\cdot}02$, $***p < 0{\cdot}01$, $****p < 0{\cdot}001$.

fluctuating noise. However, in the comfort group of emotional response, no elevation of the systolic pressure was caused by listening to music.

4. DISCUSSION

The previously reported effects of noise exposure on blood pressure showed the opposite results in a short-term experiment [2–8]. In this study, it was observed that the change in blood pressure was dependent upon the intensity of the exposure noise.

The correlation of the individual's blood pressure change in each experimental series when exposed to steady noise was significant. This demonstrated that the steady noise was homogeneous with regard to the effects on blood pressure and that the modes of blood pressure response showed the same tendencies in each individual. The relation of the individual's blood pressure change between steady and fluctuating noise exposure was not significant, however, although the L_{Aeq} intensity was the same. This demonstrated that the effects on blood pressure caused by exposure to steady or fluctuating noise were heterogeneous.

As regards the relationship between the intensity of the steady noise and the blood pressure response, the critical level was estimated to be $54L_{Aeq}$ dB. This critical level was similar to the calculated value from the averaging method of Chen *et al.* [6]. However, in the exposure to fluctuating noise, $54–57{\cdot}9L_{Aeq}$ dB was the threshold range for the critical level. It seemed that this threshold range was associated with the pressure of high-intensity peaks in the modes of fluctuation of the sound intensity level. Accordingly, it was conceivable that the ON fraction rule [9] applied to TTS growth when exposure to an intermittent noise was similarly applicable to the blood pressure.

A variety of studies have reported the effects of music on blood pressure changes [10–15] and various effects have been associated with different types of music [16, 17]. In this study, the blood pressure change was analyzed by distinguishing the intensity variation of sound fluctuation from other attributes of the music.

The changes in blood pressure index in comparisons of listening to music and exposure to fluctuating music can be interpreted as follows. Music E included a prolonged duration that did not have high-intensity peaks in the fluctuation of the sound for 65 s. The melody and timbre during that time seemed to affect the elevation of the blood pressure. The elevation in blood pressure was thus greater with music than with fluctuating noise and was marked in the comfort group of emotional response. When listening to Music R, since there was little variation in intensity in the rhythmic fluctuation, effects of melody and timbre of music were observed. However, in the comfort group, the effect was limited to effects on systolic pressure. Accordingly, the effects of melody and timbre were marked after Music R. In the third experimental series with Music S, the fluctuation was distinctly rhythmic. Accordingly, the effects of rhythm and tempo were clearly manifested in the blood pressure response to fluctuating noise. The pulse-wave did not change during any music or noise exposure conditions.

5. CONCLUSION

Both systolic and diastolic blood pressure were affected by listening to music and during exposure to noise. The critical level for the blood pressure change was estimated to be $54L_{Aeq}$ dB in exposure to steady noise.

The frequencies of high-intensity peaks in the mode of sound fluctuation were associated with an elevation in blood pressure. The melody and timbre were associated with elevations in blood pressure when listening to certain music. The change in blood pressure was slightly modified by subjective emotional responses to the music.

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