Experiment of Music Therapy Conducted at a Classical Music Recital - Measurement of Pulse Wave, Blood Pressure and Mind Orientation -

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ABSTRACT [1]

It is widely known that music affects physical and mental condition, and attempts to prescribe music instead of medicine are being made in various places. However, there are large individual differences in effects of music. Authors consider that general prescription method has not been established yet. In the present study, a music therapy experiment was conducted at an actual concert held in public. It was a piano recital commemorating the 250th anniversary of Beethoven's birth, and all the pieces played were Beethoven's. Twenty-eight subjects was women and men, aged 19 to 68. They were classified into four groups according to whether they liked classical music and whether they knew the pieces to be performed. Their blood pressure, pulse wave, cardiac orientation, hand sweat, salivary amylase, and muscle hardness were measured. Results suggested that Beethoven's piano pieces generally provide a relaxing effect on the listeners. In this paper, the experimental results are discussed, which is mainly on the pulse wave measurement conducted on four subjects, on the blood pressure, and on the directivity of the mind conducted on all subjects. Furthermore, it turned out that the method needed to be improved when experiments were conducted at an actual concert.

Keywords: Actual Concert, Pulse Oximeter, Profile of Mood States (POMS), Stress and Relaxation, Beethoven's Piano Pieces.

1. INTRODUCTION

It is well known that music has both a positive and a negative effect on the physical and mental condition. Various music prescriptions are tried in clinical practice at medical sites, for an example, music therapists may be dispatched to disaster sites [1]. The authors consider that the principle of music therapy is not understood quantitatively, and that it is used in various places based on experiential knowledge.

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In our laboratory, experiments of music therapy have been carried out for several years in order to pursue the principle of its effects. There are two methods generally proposed for the experiments. One is a method of conducting the experiment individually for each subject; while the location, date and time can be flexibly selected according to the convenience of each subject, the experimental conditions cannot be exactly the same, so there cannot be avoided the factors that cannot be understood. The other is a method of gathering subjects in the same concert [2]; while it is quite hard to promote the concert by yourself or to participate in an existing concert without any inconvenience, the experimental conditions are exactly the same except that they are sitting in different seats.

In the present study, subjects and experimental leaders participated in an actual public recital, where they conducted a music therapy experiment as the recital progressed. The authors offered the organizer and performers of the recital in advance a desire to conduct an experiment there, and obtained permission. Methods, results and discussions are described below.

2. EXPERIMENTAL METHODS

Participated Recital

The recital we attended was Beethoven's 250th Anniversary Piano Recital which was held by a non-profit organization at the music hall in Yokohama on 5 December, 2020. Its program shown in Table 1 included only Beethoven's piano pieces. The performer was a professionbal pianist, who specializes in German music. It is generally said that Beethoven's music is not suitable for music therapy because it has a strong personality and is powerful, etc., but some of the pieces played there are gentle and beautiful. It can hopefully compare whether the effects of music therapy differ depending on the pieces.

Table 1: Time schedule of the program in the recital.

Time	Contents
0:05:00	Bell for Start
0:06:15	Sonata No.20 1st Movement
0:11:02	Sonata No.20 2nd Movement
0:14:42	Variatiuon Op.34
0:27:20	Sonata No.8 1st Movement
0:35:39	Sonata No.8 2nd Movement
0:40:19	Sonata No.8 3rd Movement
0:44:45	End of Perfprmance to Intermission
1:02:27	For Elise
1:05:35	Bagatelles No.1 Op.119-1
1:07:41	Bagatelles No.2 Op.119-2
1:08:52	Bagatelles No.3 Op.119-3
1:09:27	Bagatelles No.7 Op.119-7
1:11:43	Sonata No.32 1st Movement
1:20:50	Sonata No.32 2nd Movement
1:35:50	End of Perfprmance
1:37:34	Call of End

Subjects

Twenty-eight women and men between the ages of 19 and 68 ran for the experiment as subjects. All the subjects were interested in the experiment and wanted to participate in it on their own initiative. They were classified into four groups according to whether they like classical music and whether they knew the pieces to be performed there.

Measurements

Large-scale measurements cannot be carried out in the experiment conducted in an actual concert. In addition, no matter which experimental style is adopted, it is not good to attach many measuring devices to the subject. This is because the psychological effects such as discomfort and the physiological effects such as weight and pain associated with the connection of the stylus affect the mental and physical state of the subject. We can get quite a lot of information if we can measure brain waves, but it is doubtful whether that information depends solely on the effects of music.

In the present experiment, the following six types of measurements were performed on the subject.

1) Pulse wave was measured by a pulse oximeter.
2) Blood pressure was measured by a sphygmomanometer.
3) Mind orientation was measured by POMS.
4) Saliva amylase was measured by an amylase monitor.
5) Hand sweat was measured by a measurement sticker.
6) Muscle hardness was measured by a muscle hardness tester.

3. PULSE WAVE MEASUREMENT

General Knowledge

Biometric values such as electrocardiogram (ECG), heart rate (HR) [3], brain waves and pulse waves have been measured at health examinations and clinical medicine for a long time. To estimate medical fatigue and stress [4], heart rate variability (HRV) [5], brain waves, respiratory activity, pulse waves, stress hormones, etc [6] are useful biometric information values.

The pulse wave is susceptible to the effects of stress, and can be continuously measured for a long time by a non-invasive method. The pulse wave obtained by measuring the blood flow is called blood volume pulse (BVP) [7]. BVP is analyzed directly in some case, and acceleration plethysmogram (APG) [8] obtained by differentiating BVP into the second order is analyzed in other cases. The pulse wave interval corresponds to the interval

between adjacent R waves which have the largest amplitude in the electrocardiogram waveform [9], and is used as an index of parasympathetic nerve activity instead of the heartbeat. The timing does not always match the R waves [10].

HRV corresponds to the flexibility of the heart and tends to increase with younger or healthier hearts [11]. HRV is a marker of sympathetic-parasympathetic balance, as HR increases with sympathetic activity and decreases with parasympathetic. HRV is extremely small when awake or anxious, and large when relaxed and breathing slowly. HRV can be analyzed based on the peak [15] or the power spectrum density (PSD) [14] obtained by Fourier transforming the HR history. The frequency range of 0.04 Hz to 0.15 Hz reflects sympathetic activity [12], and that of 0.15 Hz to 0.4 Hz does parasympathetic [13].

Table 2: Member list of Subjects.

Subject	Sex	Group	classical music	pieces played there
A	male	c	like	had never heard
B	female	b	do not like	had heard
C	male	b	do not like	had heard
D	male	d	do not like	had never heard
non	—	a	like	had heard

Subjects

The four of the twenty-eight subjects were referred to as subjects A, B, C, and D. They cooperated in the pulse wave heart rate measurement. All were university or graduate students in their early twenties. Subjects A, C and D were male, and subject B was female. Subject A belonged to group c, who likes classical music, but had never heard the pieces played in the recital. Subjects B and C belonged to group b (does not like but had ever heard). Subject D belonged to group d (does not like and had never heard). No subject belonged to group a. The group a includes the subject, who likes classical music and had ever heard the pieces. The member list of the subjects is shown in Table 2.

Measuring Method

The changes in HR were focused. The history of pulse rate with blood oxygen saturation (SpO_2) was measured and recorded using the specified maintenance management medical device LUKRA2800 pulse oximeter. A stylus wired to a smartphone-sized body is attached to the index finger, and the amount of infrared rays and red light transmitted through the finger along with the pulse wave, systolic blood pressure, and diastolic blood pressure were measured. This device measures the degree of redness of arterial blood and calculates SpO_2. The time, when the stylus was put on the finger, was set as the start time. The pulse rate and SpO_2 were recorded in the storage element in the main body every 2 seconds.

Each subject was seated with the pulse oximeter and operated it by him/herself to measure them. The measurement was started just before the start of the first half of the recital, was interrupted after the end of the first half, was started again just before the start of the second half, and was finished after the end of the second half. Table 1 shown above includes the track progress record of the recital. Ideally, the measurement start times of the four subjects should be synchronized. However, they were at a public recital venue, so they couldn't sit next to each other nor communicate with through a controller elsewhere. In addition, there may be slight variations in the speed at which the internal clock advances for each pulse oximeter. Therefore, after the experiment, the subjects were interviewed on timing: when they put on and took off the stylus, and what kind of subjective symptoms they had at the timing. Based on that information, their timelines were corrected by collating the measurement results with the recital progress records shown in Table 1.

Measurement of Normal Value

Before the experiment, pulse oximeters were lent to the subjects so that they could read the instruction manual and make their own measurements. They measured the normal HRs to record them on the main unit, but only subject D could save his data. His normal TR is referred to the discussion about his value HR history measured during the music therapy experiments.

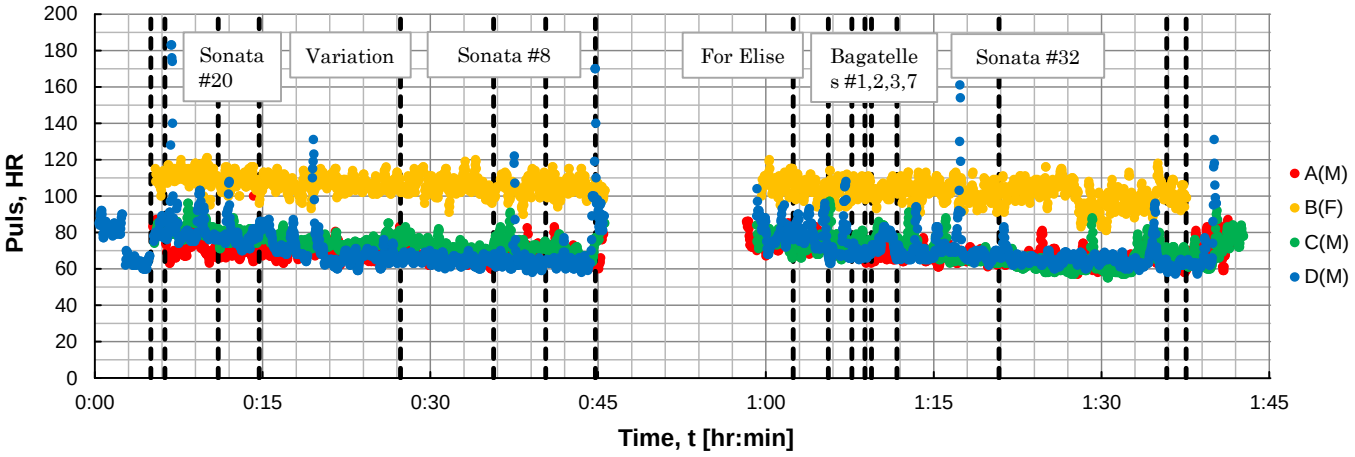
Results and Discussions

Fig. 1 shows the measurement results. The pulse histories of the four subjects are indicated by red, yellow, green, and blue marks. The black vertical dashed lines indicate the times of the beginning and the end of the first half, the second half, and pieces played (refer to the Table 1). The term before the earliest pre-bell corresponds before the experiment. Only subject D has pre-experimental normal data. All four subjects had a tendency for the pulse rate to decrease as the recital progressed. It is probable that all of them could relax by listening to the Beethoven's piano pieces and activating their parasympathetic nerves.

The result of each subject is described in detail as follows.

Subject A: HR was 72 just before the start of the recital, 66 just after the end of the first half, 78 just before the start of the second half, and 62 just after the end. It slightly decreased during the first half and clearly decreased during the second half. His daily value was between 50 and 60. He noticed that he was quite nervous during the experiment.

Subject B: HR was 114 just before the start of the recital, 107 just after the end of the first half, 107 just before the start of the second half, and 95 just after the end. It slightly declined during each half. Her daily value

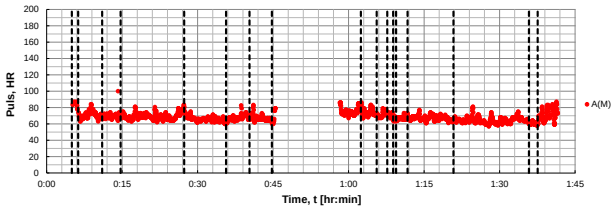


(a) Time histories of pulse HR of four subjects.

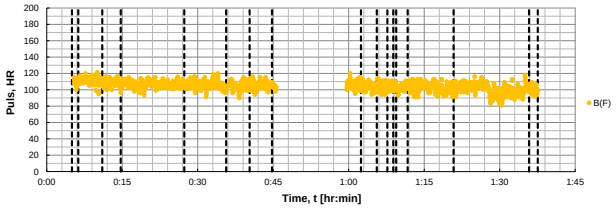
was between 70 and 80, and she was clearly nervous. She belonged to the brass band club as a high school student, and she was presumed to be accustomed to music. This may be one of the reasons why HR descent was slight. The HR fluctuation, on the other hand, was constantly about 18, which is relatively large. She reported that she might stop breathing when listening to music. At 1:28 on the time axis, HR dropped significantly, and SpO_2 at the same time also dropped to 93%. She said she didn't like "classical" music, but the phenomenon can be thought to be due to her deep listening to the piece and a temporary decrease in breathing.

Subject C: HR was 81 just before the start of the recital, 67 just after the end of the first half, 77 just before the start of the second half, and 66 just after the end. It clearly declined during the first half and the second half. His mean daily HR was 70 to 75, and he was not very nervous as he realized that he was relaxed at the experiment. At 1:29 on the time axis, it rose significantly, but he had no clue.

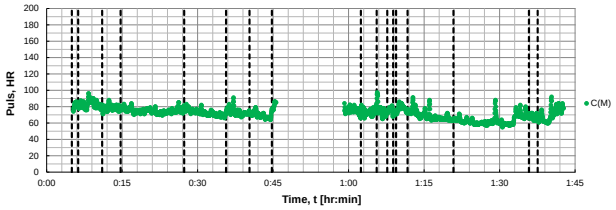
Subject D: HR was 82 just before the start of the recital, 62 just after the end of the first half, 82 just before the start of the second half, and 62 just after the end. It significantly declined during each half. His mean daily HR was between 60 and 65 according to his pre-experimental records. Even before the experiment, HR was 92. He says he has a restless and somewhat delicate, which is the reason why it was so volatile. He reported that he was excited and that he changed his posture frequently during the experiment because of the small seat. HR rose sharply just before the end of the second half, but he had no clue.



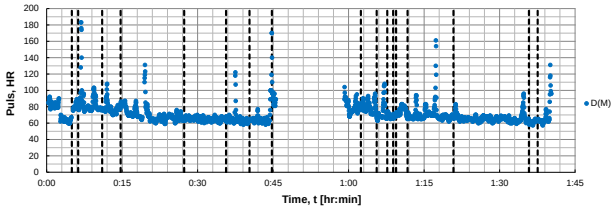
(b) Time histories of pulse HR of subject A.



(c) Time histories of pulse HR of subject B.



(d) Time histories of pulse HR of subject C.



(e) Time histories of pulse HR of subject D.

Fig. 1: Measurement Results of pulse HR.

The Effect of Listening to Known Music
Two subjects in group b showed a large pulse change at about 1:30 on the time axis as mentioned above. At that time, the pianist played the latter half of the 4th variation of the 2nd movement of Sonata No. 32, which was a very beautiful part of the treble. Subjects in groups a and b were commented on the pieces that were played in advance and were told that this part was a beautiful part. The other two subjects, on the other hand, did not know all the pieces played there. It was suggested that if you consciously listen to the music you know, the impact (reaction) may increase.

4. BLOOD PRESSURE MEASUREMENT

Mechanism of Blood Pressure [16]
The heart is an organ that is directly affected by the balance between the sympathetic and parasympathetic nerves. Therefore, blood pressure measurement can be a convenient way to assess sympathetic stress.

The arterial wall is constantly exposed to internal pressure with an average of about 100 mmHg, a frequency of about 1 Hz, and an amplitude of about 40 mmHg. Excessive hypertension [17] or hypotension causes health problems [18]. The maximum internal pressure comes out when the heart muscle contracts and tries to instantly pump the blood that was in the left ventricle to the whole body. At the moment, about 50% of the blood in the left ventricle reaches the periphery. The remaining blood in the aorta slowly begins to be pushed to the periphery, as the myocardium dilates and the aortic valve closes. The internal pressure becomes the lowest [19].

Systolic blood pressure, which is measured as the maximum pressure, is due to the ability to pump blood immediately to the periphery. It rises at the following cases: when is enhanced by increased resistance due to increased blood viscosity or narrowing of blood vessels near arteries (vascular stenosis), when blood volume increases, or when the elasticity of the aorta decreases (arteries). When the heart rate rises due to stress, the systolic blood pressure rises excessively.

Diastolic blood pressure, which is measured as the minimum pressure, increases when natural arterial restoration is impeded. It does, for examples, when the peripheral blood vessel is hardened, or when the peripheral blood vessels have poor blood flow due to blood clot, etc. When the systolic blood pressure rises, the diastolic blood pressure may rise accordingly. It may rise due to stress.

Measurement Methods
Blood pressure measurement methods are classified into two types: an indirect method (non-invasive measurement) that do not significantly damage the living body, and a direct method (invasive measurement). The indirect method measures from the surface of the body using a cuff or a sensor. The basic method performed by doctors is to listen to the Korotkoff sounds [20]. Most of automated sphygmomanometers employ the oscillometric method. Doppler method and the pulse wave transit time method are also indirect methods. Water-filled method, in which a catheter is inserted into a blood vessel for measurement, is one of the direct methods.

Blood pressure can easily fluctuate significantly due to slight internal or external disorders. Therefore, strictly speaking, it is necessary to measure 4 to 6 times or more [21]. There are many reasons for the rise. If it rises compared to normal times, it may be due to stress. The subject can measure himself with a simple home medical device. It is reasonable to measure it for the purpose of estimating the increase or decrease in stress during music therapy experiments. Since blood pressure measurement using a home medical device makes a sound, it cannot be applied in the present study: during a performance, immediately before the start of the performance, or immediately after the end of the performance.

In the present study, home medical equipment for all subjects cannot be prepared, so four sphygmo-manometers are used to be shared. In particular, the equipment used by four female subjects was entrusted to one of them. Prior to the start of the recital, all the subjects measured in the hall foyer before the arrival of the general visitor. When measuring during an intermission, the female subjects remained seated in the hall, and the male subjects moved out to a public place with sphygmomanometers. After the recital, they measured while sitting in their own seats in the hall, waiting for the audience to disappear from their seats.

Results and Discussion
Table 3 shows the systolic and diastolic blood pressure values measured by each subject at each timing. Here, the average (or M.V. somewhere), S.D. and C.V. show the mean, standard deviation, and coefficient of variation, respectively. Because they had many items to be measured, some subjects could hardly measure everything.

The mean value of systolic blood pressure was slightly lower during an intermission than before and after the intermission. On the other hand, it is hard to say that individual data show a unified tendency. In some cases, blood pressure rose after the first half. , in others it fell, In many cases, the trends in the both halves did not match.

The measurement results of the pulse wave and those of blood pressure for the four subjects were compared. HR of three subjects except subject B, who stopped measuring immediately after the end, showed a rapid

increase after the performance. Subject 11, who is subject B, also had a higher measurement value of the blood pressure after the end than the pulse wave immediately after the performance. The task of making various measurements is likely to be a type of stress that causes a rapid rise in blood pressure. The measurements during an intermission and after the end shown in Table 3 are estimated to be significantly higher than during listening to the performance.

It is not preferable to use a sphygmomanometer at a concert. It is necessary to hold a concert dedicated to the experiment or to prepare an environment where as many subjects as possible can measure the pulse waves.

Table 3: Results of blood pressure measurement.

Subjects			When they measure blood pressure						Amount of change in measured value					
No.	sex	age	before		intermission		after		int. - bef.		aft. - int.		aft. - bef.	
			max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
1	M	25	167	95	128	85	119	80	-39	-10	-9	-5	-48	-15
2	M	25	137	65	124	70	124	66	-13	5	0	-4	-13	1
3	M	23	133	80	138	86	138	85	5	6	0	-1	5	5
4	M	24												
5	M	23	138	84	130	66	137	74	-8	-18	7	8	-1	-10
6	M	23	118	64	132	92	122	80	14	28	-10	-12	4	16
7	F	24	113	77	103	71	113	75	-10	-6	10	4	0	-2
8	M	21	118	78	126	85	125	67	8	7	-1	-18	7	-11
9	M	21	136	75	129	77	109	76	-7	2	-20	-1	-27	1
10	M	22	134	90	110	94	129	87	-24	4	19	-7	-5	-3
11	F	21	118	86	108	80	134	105	-10	-6	26	25	16	19
12	M	21	114	78	137	79	95	69	23	1	-42	-10	-19	-9
13	M	20	121	51	92	70	109	54	-29	19	17	-16	-12	3
14	M	20	115	79	132	88	124	80	17	9	-8	-8	9	1
15	M	20			139	65	132	76			-7	11		
16	M	23	127	75			120	77					-7	2
17	M	21	124	71	130	77	116	77	6	6	-14	0	-8	6
18	M	22	114	81	116	79	116	80	2	-2	0	1	2	-1
19	M	21	112	78	104	76	121	72	-8	-2	17	-4	9	-6
20	M	23	135	60	135	78	121	65	0	18	-14	-13	-14	5
21	M	22	110	58			90	52					-20	-6
22	M	23	121	73	124	76	131	78	3	3	7	2	10	5
23	M	22	104	66	120	76	116	71	16	10	-4	-5	12	5
24	M	21			120	58	113	62			-7	4		
25	F	19	96	61	92	64	92	65	-4	3	0	1	-4	4
26	M	21	127	70	139	76	135	70	12	6	-4	-6	8	0
27	F	24	121	79	121	86	117	86	0	7	-4	0	-4	7
28	M	68												
Mean			123.0	73.9	122.0	77.3	119.2	74.2	-2.1	4.1	-1.7	-2.3	-4.2	0.7
S.D.			14.0	10.3	13.7	8.8	12.6	10.6	15.0	9.7	14.0	9.0	14.3	7.7
C.V.			0.11	0.14	0.11	0.11	0.11	0.14	-7.18	2.36	-8.18	-4.01	-3.42	10.92

5. PROFILE OF MOOD STATES CHECK

Background

Profile of Mood Stated (POMS) [22, 23] is the method of numerically evaluating the temporary mood and emotional states which change depending on the conditions and environment in which the respondent is placed by answering several questions. There are currently a number of research reports using POMS in a wide range of fields from the frontal lobe [24] to Zen [25]. The content of the question was translated into forty-two languages, and the Japanese version of POMS was published in 1994 [26]. It has been widely used in practice sites such as medical care, workplaces, schools. It has been used for the treatment of mental disorders, the evaluation of exercise, and relaxation effects, etc.

POMS has revised the content of the question in response to changes in language over time [27]. The latest POMS has sixty-five questions for adults and sixty for adolescents, including seven scales of mood: anger-hostility (AH), confusion-bewilderment (CB), depression-dejection (DD), fatigue-inertia (FI), tension-anxiety (TA), vigor-activity (VA), Friendliness (F). There is also a version with the number of questions reduced to 30 so that you can do it in a short time. The total mood disturbance (TMD) is calculated by Eq.(1). It is said to mean an estimate of the overall negative emotional states.

$$TMD = AH + CB + DD + FI + TA - VA \quad \cdots \quad (1)$$

Application to Current Experiments

In order to make an absolute evaluation of the mental condition, it is necessary to make a judgment by collating various cases. When we focus on the changes in mood before and after the recital on the seven scales, on the other hand, AH, CB, DD, FI, and TA may decrease if the recital affects mental and physical recovery and stress relief. In the present experiment, the time-series changes before and after the recital using a shortened version of POMS will be discussed.

The subjects were handed a questionnaire to answer it and the experiment leaders collected them before the general visitors came. They did in the same way after the recital and the general visitors went out. Since there were few desks or chairs there, the subjects were given the data in Excel format along with the questionnaire so that they could answer on their smartphones.

Results and Discussion

Overall, the value on any scale was as low as 12 or less, which confirmed that no subjects had serious mental problems. The mean value of TMD decreased by 2.4 (15%) from 15.6 to 13.2, which suggest that listening to the music performance of Beethoven's compositions reduced the negative emotional state. AH, FI, and TA also decreased by listening to the performance, and it is possible that these moods were improved. Some subjects reported that they were sleepy or calm during the recital. VA has also decreased, which may be because listening to music or listening in the hall would have a sedative effect.

The frequency distribution was obtained with a class range of 3 for each scale. Fig. 2 shows the distributions of frequencies (number of subjects) vs. class values (increments of each POMS values). The peak appears at class values of 0, which means no change in POMS throughout the recital. The frequency distribution widened more negative, that is, for many people, the

negative mood was improved after the recital compared to before.

The values of subject 20 are different from those of other subjects. For an example, the values other than FI showed the maximum of all subjects. He also increased the TMD frequency of class value 15 on POMS as shown in Fig. 2. At a later date, Subject 20 confessed that he had the next task to do after the experiment and was impatient to keep up. Subject 20 belonged to Group a (who liked classical music and knew the pieces played at the recital), and it was confirmed that the recital itself was enjoyable for him. Excluding subject 20 reduces TMD by 3.0 (19%). Since the VA value indicating the active state did not change before and after the recital, the next task mentioned above would correspond to a special reason for strongly expressing a negative condition.

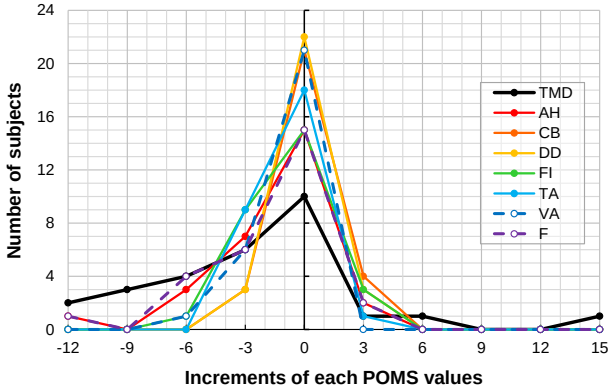


Fig. 2: Distributions of frequencies vs. class values.

6. OTHER MEASUREMENTS

Measurements of saliva amylase, hand sweat, and muscle hardness cannot complete the detailed discussion within the short pages. The authors describe them in another presentation [32]. Only the outline is described below.

Saliva Amylase Measurement
Amylase is regulated by the sympathetic nervous-adrenal medullary system [28], which can hopefully be a stress marker [29][30]. All subjects were measured using a commercially available measurement kit [31], but the measurement conditions may have varied from subject to subject. Overall, their saliva amylase decreased from 30.0 to 15.7 after the recital. However, some results showed great stress. It is necessary to evaluate the error of this measurement method.

Hand Sweat Measurement
Two types of sticker-like sensors that can measure the amount of hand sweat were prepared for each subject. The success rate of the measurement was about 66%. Two contradictory results were obtained from the sensors which worked well. First, the recital did not increase stress in many subjects. Second, stress increased slightly in several subjects compared to before and after the recital. Neither result is clear and requires accuracy verification and error analysis.

Muscle Hardness Measurement
Tests were carried out to discuss whether measuring muscle hardness could be a method to measure stress. Several subjects repeated measurement at several positions prior to the experiment using commercially available measuring device. Overall, their muscle hardness decreased from 21.9 to 17.8 after the recital. The measurement results seem to be highly dependent on the presence and type of clothing. It is necessary to consider in advance which part is to be measured by whom and how.

7. CONCLUSIONS

Music therapy experiments were conducted using an actual recital, where only Beethoven's piano pieces including sonatas No.8, No.20 and No.32 were played. In twenty-eight subjects divided into four groups, six types of biological information were measured. The conclusions obtained are as follows:

1) The pulse wave measurement results supported that Beethoven's piano music had a relaxing effect. As the recital progressed, the HR of all four subjects tended to decrease, with those who knew the music being greater.
2) POMS results and the other four kinds of measurement also suggested the same conclusion as above.
3) If the subject listens to his / her favorite music, a greater effect may be expected. As it has been considered for a long time, the authors feel that the basis of a music prescription may be to listen to the music the patient want to.
4) The sphygmomanometer is inherently too noisy to be used in an actual recital. While holding a recital dedicated to the experiment is one solution, it is simpler to ask each subject to measure the pulse wave.
5) In order to confirm the effectiveness of the muscle hardness measurement, it will be necessary to conduct a laboratory-level basic study.

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