Construction of a Music Database for Earphone Hearing Loss Prevention and Music Therapy

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ABSTRACT

The basic research regarding the effects of sound and music on humans has been conducting in our laboratory. Here, it is aimed to raise awareness of the prevention of earphone hearing loss, which has become a serious issue for young people worldwide in recent years, and to establish the principle of music therapy, which is expected as a medical treatment that does not use drugs. Then, the data base of music, which is considered necessary for both of these aims, has been started building considering its concept and constitution.

This paper introduces the music database built up to this point. In addition, how to use the data base for ear age estimation in earphone hearing loss prevention research and sound effect estimation in music therapy research is proposed. In preparation for the music therapy experiment held by participating in the Beethoven 250th Anniversary Piano Recital, all of 32 Beethoven piano sonatas, 9 symphonies, and 16 string quartets have been added to the database.

Keywords: Pop Music, Rock Music, Beethoven's Symphony, Beethoven's Piano Sonatas, Beethoven's String Quartets.

1. INTRODUCTION

In recent years, earphone hearing loss (deafness) has become a serious issue worldwide, especially among young people [1][2]. In our laboratory, the basic research has been continuing with aiming to quantitatively elucidate the mechanism, to prevent and enlighten earphone hearing loss while [3][4]. In recent years, the streets have been flooded with sounds and music, and it is important to make effective use of them (music therapy, etc.) while avoiding their adverse effects. In our laboratory, the basic research has been continuing for quantitatively elucidating the mechanism of music therapy [5][6].

The authors consider that a data base of sounds and music is necessary for both of prevention of earphone hearing loss and effective use of sound and music. In our laboratory, the appropriate concept and constitution (structure) of the database have been discussed with thinking about how to apply the databases to the actual problems, and the data base has started to be constructed [7][8]. In the present paper, the music database that has been built so far is introduced. Then, the specific methods for using this database for estimating ear age in earphone hearing loss prevention research and for estimating sound effects in music therapy research is introduced.

2. BASE CONCEPTIONS

Burden on the Ears

Earphone hearing loss, which we study on, is a symptom of accelerated age-related hearing loss and is thought to be caused by the destruction of hair cells in the inner ear. That is, the root

cause of earphone hearing loss is sound energy. Therefore, the music database should have the sound energy of each piece as its element.

Hair cells are arranged in the cochlea in a finely corresponding frequency. For example, some hair cells are for listening to 1000Hz sound, and some are for listening to 10000Hz sound. Since which frequency the hair cell corresponds to depends on the resonance frequency determined by the cross-sectional shape of the basement membrane, it is considered that the shape and strength of hair cells do not differ depending on the corresponding frequency (the authors have not yet obtained information on this matter). Hair cells are damaged by the sound energy of the corresponding frequency of sound coming in from the ear. Hair cells corresponding to 1000Hz are not considered to be damaged by the sound of other frequency of sounds, for an example, 10000Hz. However, it is structurally impossible to resonate at pinpoint only at the cross-sectional part of the basement membrane that shows the natural frequency of 1000Hz when the sound of 1000Hz is input, so it is speculated that the basement membrane will resonate so that the center position becomes the swing width peak in the (small) frequency range around the corresponding frequency, such as 950Hz to 1050Hz for an example. As long as this frequency range is unknown, even if a database is created by carving frequencies into small pieces unnecessarily, there is a risk that versatility will be impaired.

In the previous report [3], the human audible range of 20Hz to 20000Hz is divided into 3 parts: a low frequency range of 20Hz to 200Hz ($10^{1.30103}=20$), a medium frequency range of 200Hz to 2000Hz, and a high frequency range of 2000Hz to 20000Hz. The frequencies were represented by 100Hz, 1000Hz, and 10000Hz for these ranges, and it was able to evaluate the ear energy to some extent. However, the ranges divided into narrower ones are necessary for a more rigorous evaluation. In this study, we compared the case where the music in the database was divided into the above three and the case where it was divided into 6 as follows: the audible frequency range is divided into 6 which are an extremely low frequency range of 20Hz to 63.25Hz ($10^{(1.30103+0.5)}=63.245554$), a low one of 63.25Hz to 200Hz, a low medium one of 200Hz to 632.5Hz, a high medium one of 632.5Hz to 2000Hz, a high one of 2000Hz to 6325Hz, and an extremely high one of 6325Hz to 20000Hz, and the frequencies of each region were represented by 50Hz, 160Hz, 500Hz, 1600Hz, 5000Hz, and 16000Hz. Here, how to divide the region is an issue that should be discussed and solved in the future.

In the calculation of sound energy, a spectrum obtained by Fourier Transforming sound data in WAVE format is required regardless of how many divisions the frequency is divided into. Therefore, the authors decided to include the spectrum analysis results as elements in the database. Based on the results of classification by the method proposed in the present study, comparing how much the sound energy varies in each group were carried out to discuss the validity of the classification.

Direction of Action on the Mind

The music therapy we study on is used for a variety of purposes. For example, it may restore a depressed feeling, or it may calm an excited feeling. It may be possible to use it for the treatment of colds in the future. Depending on the purpose, the principles and methods that music prescriptions rely on should also differ. In any case, music has a direct psychological effect rather than a physiological effect. Therefore, the authors consider that music changes the state of mind, and in this study, for the sake of simplicity, only one axis that indicates the state of mind $H(t)$, albeit vaguely are provided.

While 7 mood scales are set in POMS [9][10], it is considered that each of them is fundamentally related to how active the mind is and how the activity of the action is about to change. In this study, the state of mind is regarded as an index such as the degree of activity of the mind. The negative side of the state value means sedation ($-\infty$ means stopping biological action), positive side means excitement ($+\infty$ means runaway biological action), and the appropriate balanced position is around 0. It is considered that the state of mind $H(t)$ increases or decreases according to the energy E input from the outside and also depending on the mental activity or mental state (the latter amount of change is represented by ΔH.). Then, the state of mind $H(t)$ at time t is calculated from the state of mind $H(t-\Delta t)$ as shown in equation (1), where Δt means a small time elapsed. This hypothesis must eventually be confirmed and examined by music therapy experiments. While how the energy E input from the outside changes the state of mind may depend on the state of mind $H(t)$ at that time and how the state of mind is about to change dH/dt, those dependencies are ignored In this study. In addition, causal analysis of increase / decrease ΔH due to mental activity and mental state is a future task.

$$H(t) = H(t-\Delta t) + func.(E) + \Delta H \quad \cdots\cdots\cdots \quad (1)$$

Based on this hypothesis, the music database should have the total energy E of the music as an element. The energy E can be calculated as the sum of the sound energies for each frequency range described above.

There are many experiences in which the intonation of music is thought to influence the ups and downs of the mind. It may be that the state of the mind $H(t)$ may increase or decrease not only by the energy E but also by the fluctuation of the input energy. In this way, even if only one state axis of the mind is provided, many mechanisms of action can be considered. In order to discuss the intonation of music, time-series information of music is needed. There are many issues that should be resolved in the future.

Evaluation Value for Sound Energy

The energy flux ϕ [J/m^2·sec] of the standing sound wave which is transmitted in the medium of density ρ [kg/m^3] at speed c [m/sec] and whose amplitude is A [m] and frequency is f [Hz] [4][10] can be calculated by Eq. (2).

$$\phi = 2\pi^2 \rho c A^2 f^2 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

In the case of a mixed sound consisting of partial sounds i, equation (2) is expressed as equation (3).

$$\phi = \sum_i \phi_{f_i}\ ,\ \phi_{f_i} = 2\pi^2 \rho c {A_{f_i}}^2 {f_i}^2 \quad \cdots\cdots\cdots \quad (3)$$

The calculation of the energy flux of the spectrum can be done in the same manner as that of the mixed sound. While the spectrum obtained by Fourier Transforming music has a continuous distribution, there are 2 methods to calculate its total energy flux, one is to consider only large peaks and the other is to integrate on the frequency axis. It is generally said that the former has sufficient accuracy. The spectrum output by the program on the PC is digital data that consists of many partial sounds in fine frequency increments.

3. CLASSIFYING MUSIC

Essential Purpose and Policy

It is difficult to classify existing music because music has been a fusion of various fields in history. Music made by the artists of so-called Generation Z (generations born after around 2000) often does not fit into the conventional classification.

In our laboratory, the authors are constructing a music database by classifying music for the purpose of quantitatively evaluating the "burden on the ears" and the "direction of action on the mind" of the music people listen (listened) to. "Burden on the ears" is necessary information for estimating ear age, and "direction of action on the mind" is that for considering the use in music prescriptions. On the other hand, new music is constantly being supplied to the world, and it is impossible to create a database that includes all existing music. The purpose to classify music in this study is to group music that has the same (similar) "burden on the ears" and "direction of action on the mind" into the same group, and to infer which classification it is likely to belong to when you touch music that is not yet in the database.

Therefore, the viewpoint of music classification in this study should be "burden on the ears" and "direction of action on the mind". For example, considering classical music, there are quiet songs which are less burdensome to the ears, are big songs which hurt an ear, are brave songs which activate the direction of action on the mind, and are sad songs which calm down. There is a possibility that the general classification by genre cannot always be applied as it is.

Art Music

First, artistic music should be separated from the others. This is because that the composer's own strong message is often included in the creative motivation to express independent beauty, and that, as its result, the music may shake the listener's heart violently. Gagaku is regarded as an art in Japanese music, but there are also the works for the gods and the imperial family that may have little artistry and better to be considered these separately as discussed later. Classical music is typical example which is under this category in Western music. Some art music may have been composed in the name of a dedication to God, but they should be classified as art music since the purpose of this classification is the effect on the listener. For example, Beethoven's piece presented to the aristocrat who helped him financially is artistic music and is not considered to be music of the upper class.

Heavy Metal Music

While there are various opinions about the difference between rock music and rock'n'roll music, the theory that rock music is the Caucasian music, which lacks the element of African-American music [11][12] from rock'n'roll music, is considered to be the most influential. According to this theory, Elvis Aron Presley is a rock'n'roll musician, and The Beatles is a rock band. Hard rock music, which adds elements such as high-pitched shout (screaming), heavy sound pressure, and flashy guitar play to rock music, became a boom in the early 1970s. Hard rock music, where the guitar and bass guitar are electric instruments, can be said to be loud and aggressive rock music. Heavy metal music makes hard rock music even faster, heavier, and incorporates the elements of classic music. Deep Purple and Led Zeppelin are some of the bands which connected hard rock music to heavy metal music.

One of the elements of classic music incorporated into heavy metal music is the inclusion of ideas. Second, heavy metal music theory and playing methods are based on classical music. Yngwie Malmsteen, for an example, adopted the high-speed guitar playing style influenced by Paganini's violin solo and the harmonic minor scale used in Beethoven's the 8th piano sonata “Pathétique” or Chopin's etude “Revolution” in heavy metal music. The harmonic minor scale, which raises the sound of the 6th note So by a semitone, creates tension and thrills with an augmented second interval that exists in the middle of the scale. Third, the shout is an extension of the classical vocalization. Thomas Vikströmm who is a heavy metal singer and a classical tenor singer, said that he makes a lustrous voice (clear voice without faintness) and a husky voice for classical music and heavy metal music, respectively. Unlike hard rock music to get the sympathy of the general public as popular music (pops), it would be rather conceptual like classical music.

Music for God and Upper Classes

In the history of music, there is a lot of music dedicated to God and nature. Kagura (a kind of gagaku) and buddhist music are the examples of Japanese music, and religious music is the example of overseas music. The music dedicated to God will be what appeals to the feelings of respect and fear without making too much noise rather than expresses human emotions. Some Christmas songs also correspond to such music as hymns. Considering the history of mankind, each country has music for God.

It is ambiguous whether the requiem which was composed on the Bible is for God or for people. For example, Mozart's requiem expresses intense emotions with his own feeling. Some requiems should not be classified as music dedicated to God or nature.

Music that is not religious music for God is generally called

Table 1: First step of classification the data base refers to.

			Japanese music		European music		American music	
true object to give			traditional music	non traditional music	classical music	non classic music	Caucasian music	black music
God and nature			kagura		Christian music		Caucasian spirituals	African-American Spirituals
mankind	royal aristocrats or upper classes		court gagaku		secular classical music			
	beauty or thought		art gagaku		art classical music			
	ordinary person	for army	–	Japanese pop music	a part of classical music	European pop music	American pop music	
		for child	–	Japanese army music		European army music	American army music	
		for worker	Japanese murseru music	–		European mursery music		
		for folk		–				African-American work music
			Japanese folk music			European folk music	country music	jazz, blues
			soukyoku				rock and roll music	
			nagauta, johruri music			rock music		
						hard rock music		
						heavy metal music		

secular music. The classical music and heavy metal music discussed above are also secular music. Secular music is diverse. It seems necessary to classify secular music into the music about upper class, for examples the back ground music (BGM) used for upper class events, and music that expresses the life of upper class, and other music. This is because that the composer's own will is basically not included in the music, and that, as its result, the character of the music may not be as emotional as, or less emotional than the music dedicated to God. The music is treated as disposable in some case. Such music corresponds to some gagaku in Japanese music and court music in Western music.

4. DATA BASE ON CONSTRUCTIOIN

Overall Image

First, how to classify classical music and pops was considered, because it can be thought that university students and their friends and acquaintances, who would be the first experimental subjects in the future, probably listen to classical music and pop music on a regular basis. Pops is used as a general term for popular music that has been accepted by the general public at that time. As mentioned above, African-American music (blues, jazz, etc.), American Caucasian music (country, etc.), rock'n'roll music, rock music, hard rock music, heavy metal music should be subdivided rather than in the same group “pops” in this study. The authors have previously collected various pieces, and many pieces including to the classical music, hard rock, heavy metal, and other pop music were added to the data base to be mentioned the characteristics of each genre.

Table 1 shows a classification for the music dealt with in the above discussion. This classification is not yet complete. In the future, the classification will be improved and updated while the database is constructed. Database construction for art music and hard rock music, which are the groups shown in yellow in Table 1, and other pops is progressed. Table 2 lists the number of pieces in each genre (group) which have been or are being added to the database. The classified songs were first saved with WAVE data and then were searched for MIDI data. WAVE data was provided to the frequency-analysis to obtain a spectrum which the sound energy was calculated based on. MIDI data was input to the analysis program, and the distribution of the number of pitches used was output. It is presumed that the spectrum and this distribution will be relatively similar.

Classical music and Beethoven’s Pieces

Beethoven's 9 symphonies, 32 piano sonatas, and 16string quartets have been analyzed to be added to the data base, because they were compared with heavy metal, which contains a message like classical music as mentioned above, in honor of the 250th anniversary of his birth. On the other hand, Fig. 1 shows the averaged frequency analysis result of classical music that has been added to the conventional database before Beethoven’s pieces mentioned above. In Fig. 1, the product of the square of the amplitude and the frequency were calculated as energy factors, which is proportional to the amount of energy, and summarized corresponding to the case in Table 3 where the frequency region of 20Hz to 20000Hz is divided in 1, 3, and 6.

Rock Music, Hard Rock Music and Heavy Metal Music

The pops that Japanese young people prefer listening to was investigated, and rock music was separated from them. Next, the hard rock music was separated from the rock music, and

Table 2 : List of pieces classified and added to data base.

group	musical instrument organization									number of pieces
	Oc.	S.Q.	4p	P.F.	Vn.	Kb.	Gt.	K.H.	Sa.	
heavy metal			1							1
	before organizing									6
hard rock			1							1
			1			1				3
			1	1		1				1
	before organizing									12
rock			1							14
			1	1						1
			1			1				1
			1	1		1				3
			1	1				1		1
			1	1	1					1
			1		1		1			1
	before organizing									184
pops			1	1						2
(not include above music)			1		1					1
			1	1	1					1
			1	1		1			1	1
	before organizing									779
classical				1	1	(Bach)			*	1
	1			1		(Beethoven)				9
		1				(Beethoven)				16
				1		(Beethoven)				38
		1		1		(Brahms)				1
				1	1	(Brahms)			*	1
				1		(Dobussy)				18
				1	1	(Dobussy)			*	1
				1	1	(Dvorak)			*	2
	1			1		(Chopin)				1
				1		(Chopin)				49
				1	1	(Chopin)			*	2
						(Liszt)				4
		1				(Mendelssohn)				1
				1		(Mozart)				4
				1	1	(Pachelbel)			*	1
				1	1	(Rachmaninov)			*	1
	1			1		(Rachmaninov)				1
				1	1	(Ravel)			*	1
		1		1		(Schubert)				1
				1		(Schubert)				8
				1		(Schumann)				5
				1	1	(Schumann)			*	1
Animation	before organizing									16
Jazz	before organizing									16
folk				1	1	(Russian)			*	1
	No other instrument of the song specified									9

Oc. for Orchestra
S.Q. for String Quartet, Vn for Violin (Solo)
4p means standard set, E.G., E.B., D.S. and Vo.
E.G. for Electric Guitar, E.B. for Electric Bass-Guitar, Gt. For Guitar
D.S. for Drum-Set
Vo. For Vocal
P.F. for Pinao-Forte (Solo)
Kb. for Electric Keyboard
Sa. for Saxphone
* means not original but Violin arranged

then, the heavy metal music was separated from the hard rock music. The averaged frequency analysis results of these music groups are shown in different colors in Fig. 1. Also, as with classical music, the energy factor was calculated and shown in Table 3. Compared to classical music, they looked quite different in spectrum. On the other hand, pops, rock music, hard rock music and heavy metal music had almost consistent spectra. Since air check (volume adjustment) is done when creating WAVE data, music with a certain volume or more tends to have a similar spectrum. It may be that the volume (sound energy) which comes into the ear will be different when listening to these music live, and that the listener will surely choose the volume according to the music when listening with earphones.

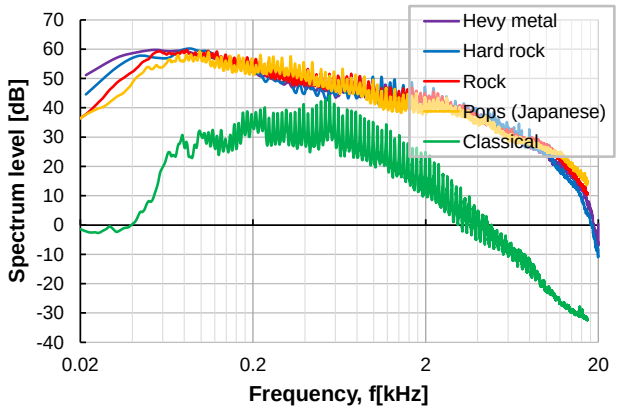

Fig. 1 : Results of frequency analyses.

Table 3 : Comparison of energy factors between music groups.

(a) Energy factors.

Division methos		Group of music				
Number	Frequency regions	Classical	Pops (Jpn.)	Rock	Hard rock	Hevy metal
1	20 - 20000Hz	2214	835630	751353	580893	657989
3	20 - 200Hz	2	8	8	8	8
	200 - 2000Hz	1160	4691	5243	5302	5086
	2000 - 20000Hz	1052	830931	746102	575582	652895
6	20 - 63.25Hz	0	0	0	0	0
	63.25 - 200Hz	2	8	8	8	8
	200 - 632.5Hz	86	200	195	172	173
	632.5 - 2000Hz	1073	4491	5048	5131	4913
	2000 - 6325Hz	1052	89587	94014	104980	100346
	6325 - 20000Hz	0	741344	652088	470602	552548

(b) Energy factor ratios to classical music.

Division methos		Group of music				
Number	Frequency regions	Classical	Pops (Jpn.)	Rock	Hard rock	Hevy metal
1	20 - 20000Hz	1	377.3	339.3	262.3	297.1
3	20 - 200Hz	1	3.2	3.4	3.3	3.2
	200 - 2000Hz	1	4.0	4.5	4.6	4.4
	2000 - 20000Hz	1	789.7	709.1	547.0	620.5
6	20 - 63.25Hz	1	16.7	19.4	15.5	17.0
	63.25 - 200Hz	1	3.1	3.3	3.2	3.2
	200 - 632.5Hz	1	2.3	2.3	2.0	2.0
	632.5 - 2000Hz	1	4.2	4.7	4.8	4.6
	2000 - 6325Hz	1	85.1	89.3	99.8	95.4
	6325 - 20000Hz	0	∞	∞	∞	∞

The energy coefficient values of 0 shown in Table 3 indicate that they are extremely close to 0. The values corresponding to the region of 20Hz – 63.25Hz are shown as 0 because the frequency is small. On the other hand, the value of the energy coefficient of classical music corresponding to the high frequency region of 6325 Hz to 20000 Hz is shown as 0. The reason is considered that classical music tends not to use high frequency sounds. Ignoring the overtones, the highest pitch of the piano, one of the highest-pitched musical instruments used to classical music, is 4186Hz. However, it would be that a good approximation result can be obtained even with 3 division method, because the shape of the spectrum is smooth, that is, there is no frequency where the energy coefficient changes rapidly.

5. CONCLUSIONS

The data base of music, which is considered necessary for researches of earphone deafness and music therapy, has been started building considering its concept and constitution. The conclusions obtained are listed as follows;

1) The classification of music is in progress. As the usage of music databases is developed and improved, the classification will be revised.
2) The data currently provided in the database are WAVE data and MIDI data which the amount of energy and the shape of the spectrum are investigated base on.
3) Classical music has a different spectrum and produces less treble than pop music.
4) It can be considered that the difference between hard rock music, including heavy metal music, and other pop music is the volume, not the shape of the spectrum.

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