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Investigating the Relationship between Therapeutic Music and Emotion: A Pilot Study on Healthcare Service

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Abstract. Life of modern people becomes more convenient and rich in material side but worse in mental side due to life stress. This results in bloom of some diseases such as insomnia. Listening to music could be one way to make people feel smooth. Some previous literature had advocated the efficiency of music therapy, however, only a few previous studies discussed and connected personal cognition (subjective indicators) with music features (objective indicators). Therefore, the aim of the study is to investigate what kind of music characteristics can spiritually relax people and obtain the therapeutic music from above results. Firstly, this study collected 25 different styles of music as samples. These songs were classified with Fuzzy C-Means clustering algorithm. According to our experimental result, music with mild amplitude, slow speed, and positive feelings can enable soothing in mind. The findings would also fit in with physiological signals (Heart Rate Variability) to ensure the consistency in psychology and physiology. This finding can provide suggestions on selection of therapeutic music. In addition, musicians can compose appropriate therapeutic music for patients of different mental illness.

Keyword. Music Therapy, Fuzzy C-Means Clustering Algorithm, Personal Cognition, Heart rate variability (HRV)

Introduction

As the growth of economics and development of technologies, people's life became more adequate and convenient. However, pursuing material benefits often makes our mental side being under pressure. Psychologist had pointed out that regularly low quality sleep has high probability to cause chronic fatigue and results in many physical or mental illness such as constipation, headache and hypertension. In order to effectively relieve psychological stress, music is considered as one of effective ways to cease the problem. In 1800s, music has been utilized to improve the sleeping quality, and research also showed that some unique melodies and rhythms of music can release blood pressure, and slow down both basal metabolism and breathe rate. In recent years, music therapists also adopted music in the medical procedure as treatment because therapeutic music has the efficiency on releasing of pressures (Cevasco et al., 2005).

According to two-dimensional emotion representation in Thayer's model as Figure 1 shown, the emotion of human can be divided into two dimensions from silent

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to energetic and from negative emotions to positive emotions (Taylor, 2001). There are various styles of music, and the purpose of this study is to search for music characteristics that can guide a peace and harmonious status on people. Therefore, this study will categorize the "positive" and "silent" music by clustering music styles. With appropriate music, some healthcare services may be improved since music has ability to comfort people. After clustering music styles, the psychological and physical experiment will be conducted to examine if these music indeed have effectiveness, and this research expects to investigate the steady state of psychology and physiology on human as so to stay healthier.

Figure 1. Two-dimensional emotion representation in Thayer's model (Taylor, 2001)

1. Literature Review

1.1 Physiological signals and Emotion

The emotion can be mainly expressed as adjective such as happy, angry, sad, calm and so on. As shown in Figure 1, the model used "Energetic" and "Calm" to indicate the degree of emotional energy, and it used "Happy" and "Anxious" to indicate the degree of emotional stress (Han, 2010; Gaston, 1951).

Heart rate variability (HRV) analysis is the most direct and obvious index of regulated emotional responding (Appelhans& Luecken, 2006). The ratio of low frequency to high frequency (LF/HF ratio) is one of the HRV measurements and it can measure the balance of autonomic nervous system (ANS) (Ellis& Thayer, 2010). ANS can be divided into two subsystems: the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS) (Dorland, 2011). In general, PNS indicates the decreasing of heart rate, blood pressure and relate to smooth emotion; SNS indicates the increasing of heart rate, blood pressure and relate to energetic emotion (Kim & Kim, 2004). Increases in overall variability LF/HF ratio (also means the excessive secretion of SNS) have been described in many pathologic states, including heart disease, diabetic neuropathy, spinal cord injury, and severe brain injury (Winchell& Hoyt, 1996).

1.2 Music therapy

The aim of music therapy is to establish a health service that is similar to occupational therapy and physical therapy using music therapeutically to address physical,

psychological, cognitive and/or social functioning for patients of all ages (Bruscia, 1989). Kerr (1942) had conducted sample surveys for the patient who is ongoing music therapy, in which 90% of the sample believes that music can reduce fatigue, and 88% of the sample believes that music will ease the mood. There are also many studies indicated that music therapy have a significant impact on the operation in autonomic nervous system of people (Witkin,1954), and the autonomic nervous system plays an important role in physiological functions such as heart rate variability, respiration, blood pressure, digestion and metabolism .

Based on above literatures, music therapy is helpful for psychology and physiology of people. Accordingly, some specific styles of music can soothe the soul and physiology reaching to a steady state. Finding the music which can reduce the excessive secretion of SNS are not only beneficial for people's emotion and mental illness, but also helpful for the prevention of heart disease.

1.3 Music clustering methods and clustering index

The current music classifications can be divided into two directions: one is based on music content (music content-based) to analyze the classification, including the melody, rhythm, chord and other music characteristics as a basis for classification (Lin, 2004; Brecheisen, 2006); another classification is based on learning machine, such as linear analysis, Bayesian analysis and artificial neural network approach to music classification (Loh, 2006; Mandel, 2008). Levitin (2011) has proposed that the basic elements of music are pitch, rhythm, tempo, contour, timbre, loudness (amplitude) and response. Fu (2011) organized the four categories of audio features into the two-directional diagram based on the short and long term, and music-oriented features. Figure 2 shows that music features can be divided into long-term characteristics with moderate tone, harmony and rhythm; beats with long-term and low level of eigenvalues; timbre with short-term and low level of eigenvalues.

1.4 Summary

In the following music clustering indicators, this study mainly adopted clustering based on the physical properties. However, "*Emotion*" is a word difficult to objectively defined and only analysis in the physical properties might cause the error. Therefore, this study will consider the classified characteristics and physical characteristics (amplitude, velocity) at the same time. Fuzzy algorithm would be applied to translate the uncertainty of emotion in order to conduct the analysis.

2. Methodology

The purpose of study is to find the soothing music by using Fuzzy C-Means Clustering Algorithm with classifying the music style in first priority. After finding the target group of music (silent and positive), an experiment with ergonomic principle is conducted to verify whether the positive and silent music can soothe people's emotion effectively.

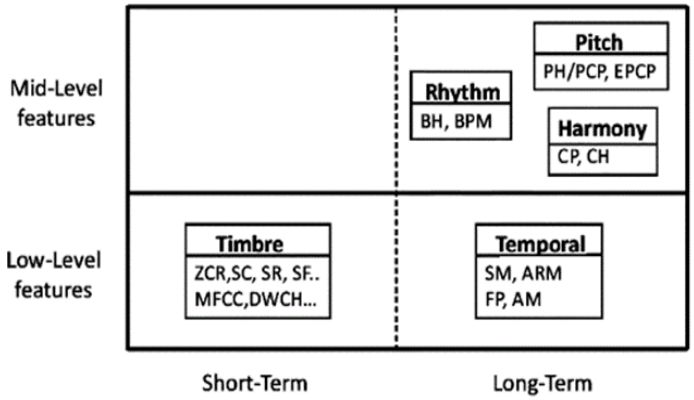

Figure 2. Characterization of audio features (Fu, 2011)

2.1 Data collection

This study first determined the number of music to be analyzed, and considered of physical and psychological characteristics of music as objective and subjective indicators. The objective indicators include the variability of music rhythm and amplitude, while the subjective indicators include psychological characteristics of positive and negative emotions. Then, the indicators that related to the membership function are defined and analyzed. The membership functions of the three indicators are represented as the following formula:

(1) Membership function with low level of amplitude variability

$$\mu_1(x) = e^{-\frac{1}{220}x^2}, \quad x > 0 \tag{1}$$

(2) Membership function of slow music

$$\mu_2(x) = \begin{cases} 1, & 0 \le x < 1 \\ \frac{1}{2} - \frac{\sin\left(\frac{\pi}{4} * (x-3)\right)}{2}, & 1 \le x < 5 \\ 0, & x \ge 5 \end{cases} \tag{2}$$

(3) Membership function of music to give people positive emotions

$$\mu_3(x) = \begin{cases} 0, & 0 \le x < 1 \\ \frac{(x-1)^2}{16}, & 1 \le x < 5 \\ 1, & x \ge 5 \end{cases} \tag{3}$$

(4) Define high comfort level music by the following membership function (μ_4) as follows:

$$\mu_4(x) = \begin{cases} 0, & 0 \le x < 1 \\ \frac{(x-1)^3}{64}, & 1 \le x < 5 \\ 1, & x \ge 5 \end{cases} \tag{4}$$

2.1.1 Average amplitude variation

Using well-known music software "*Max*" to analyze music, and after calculating amplitude for every second, the amplitude variance of whole song will be found and considered as indicators.

2.1.2 Tempo

Our research set five kinds of major changes for music tempo, including *Lento, Andante, Moderato, Allegro* and *Presto* (Sachs, 1988), and rating it with the range of value 1 to 5. Some fine-tuning are needed when the same as the adagio song but not exactly the same speed. For example: two songs are belongs to Adagio, but one is faster, then the speed evaluation may be1.25, 1.5, 1.75 ... and so on. These indicators are measured by physical characteristics, and the analysis focused on the music itself.

2.1.3 Degree of comfort

Since that the positive mood belongs to the subjective feelings of listeners, this study conducts experimental design with questionnaire. Detailed procedures of the experiment is shown as follows:

(1) The participants entered the laboratory.

(2) Play music that each song is about 1 to 3 minutes.

(3) After playing music, the participants had 30 seconds to answer the questionnaires:

(4) Play 30 seconds of natural sounds to avoid the interference generated.

(5) Play the next song and circle back to step (3) until the whole songs finished.

(6) Finish songs playback and end the experiment.

2.2 Fuzzy C-Means Clustering

We converted the rhythm of the music and the forward degrees of the music into appropriate data by using the fuzzy relations function and the original data of the degree of amplitude variability that mentioned in the previous sections. Fuzzy C-Means clustering would be used to deal with these data as follows:

$$\text{Min z} = \left(\widetilde{U}\right) = \sum_{i=1}^{c}\sum_{k=1}^{n}(\mu_{ik})^{m}\|x_k - v_i\|^2$$

$$\text{s.t. } v_i = \frac{\sum_{k=1}^{n}(\mu_{ik})^{m}x_k}{\sum_{k=1}^{n}(\mu_{ik})^{m}}, \forall i$$

where m_1 is a given number

According to Thayer's model, this study expects to find the positive and silent music. The process of Fuzzy C-Means Clustering Algorithm is shown as follows:

Step 1. According to Thayer's model, this study expects to find the positive and silent music. So, the number of clustering c ($2 \le c \le n$) were defined to be 4, which is the number of four clusters, and the weight m ($1 < m < \infty$) was taken the general values:
2. Next, these raw data will be transferred to define as $x_k = [\mu_1(x_k), \mu_2(x_k), \mu_3(x_k)]$, $\mu_{ik} \in [0,1]$ in the matrix$\widetilde{U}^l$ will be established. Further, since for any point x_k, the sum of the degrees in individual clusters should be exactly equal to 1, the following equation must be satisfied:

$$\sum_{i=1}^{c}\mu_{ik} = 1, \forall k \tag{5}$$

Step 2. Using the following formula to calculate for each center of clusters v_i.

$$v_i = \frac{\sum_{k=1}^{n}(\mu_{ik})^m x_k}{\sum_{k=1}^{n}(\mu_{ik})^m} \quad (6)$$

Step 3. Calculate the new matrix $\widetilde{U}^{l+1}$ in accordance with following equation with v_i.

$$\mu_{ik} = \frac{\left[\frac{1}{\|x_k - v_i\|_G^2}\right]^{1/(m-1)}}{\sum_{j=1}^{c}\left[\frac{1}{\|x_k - v_i\|_G^2}\right]^{1/(m-1)}} \quad (7)$$

Where, $\mathrm{i} = 1, \ldots, \mathrm{c}; ; \mathrm{k} = 1, \ldots, \mathrm{n}$

Step 4. Calculating $\Delta = \left\|\widetilde{U}^{l+1} - \widetilde{U}^{l}\right\|_G$. If Δ is greater than specific standard, 1 will be set as l +1 and start from Step 2 again. If Δ is below specific standard, end computing.

2.3 Comparative Analysis

In this phase, we compared and analyzed the different clusters according to the soothing music of subjective decision and the result of fuzzy clustering and verify whether subjective ratings and objective data analysis is consistent or not.

2.4 Identify the characteristics of soothing music

According to the result of Section 2.3, we compiled the common characteristics and relationships of rhythm, amplitude variability and positive emotion in the same group of soothing music.

2.5 Validation of physiological signals

After finding the relationship between physical indicators (music rhythm, amplitude variability) and positive emotions, we began to find the relationship between physical indicators and physiological signals (HRV was used as an indicator here). Also, how the different music styles affect the physiological signals is interested in this research. As the result, we conducted an experiment with ergonomic principles to verify the relationship.

3. Case Study

3.1 Data collecting and experiment

The whole experiment of the study can be divided into two parts. The first part is to classify the target music style and compare the clustering results with psychological result. This study selected 25 different styles music for analysis, and there are four subjects in the experiment. Experimental procedures were described in Section 2.1. All subjects would be asked “How comfortable this song brought to you?” and “How positive this song brought to you?” within 30 seconds. The two questions are in forms of *Likert scale* by questionnaire. The greater the value represents and the more comfortable/possible the song is. Finally, the results of the questionnaires and physical signals would be converted into relative functions.

The second experiment were cooperated with Industrial Technology Research Institute (ITRI). Listening five homemade songs, 10 subjects (which have been working in ITRI, five men and five female and they are between the ages of 50 to 60) joined in this experiment. All subjects would hear five songs and the nature sound in interval to avoid unnecessary interruption. Besides, the subjects worn on the wrist strap with a sensing device to secure the HRV related signal during the sound play and they would be requested to answer a questionnaire to pair the suitable emotion themselves toward different music. After the experiment, the indicators of music and the five different music styles would be compared with the HRV of each subject.

3.2 Data clustering and analysis

3.2.1 Fuzzy clustering result

This study used the software *Matlab2012a* which was published by *The MathWorks* to analyze above data, and the clustering results are as follows:

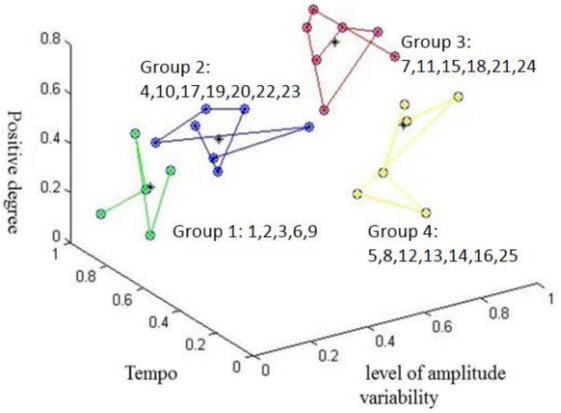

Figure 3. Fuzzy clustering results

Figure 3 show the results of fuzzy clustering, and Figure 4 is the result of questionnaires by converting the soothing relationship function. As shown in Figure 3, group 2 largely fit in with the soothing music (membership degree greater than or equal to 0.8). Thus, we had analyzed the three indicators of group 2, it had a lower level of amplitude variability and the tempo was slow. However, the tracks within Group 2 are belonging to high positive degree. This result could exactly fit in the reality of the true feelings. In general, people feel comfortable in a song that wouldn't have high level of amplitude variability, slow tempo and bring people more positive feelings.

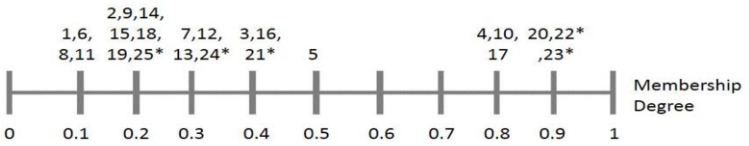

Figure 4. The results of subjective questionnaires

3.2.2 HRV related signals in music

After finding the soothing group of music, this study selected five homemade songs from track 21 to 25, and examined the HRV related data of all subjects to verify if the physiological signals correspond with psychological response and physical properties of music. Each subject's HRV related data and pattern are shown as Figure 5. Due to error and missing data occurred, we excluded the data of some subjects and only remained effective sample: Subject 1, 2, 5, 7 and 8. Here, this study used LF/HF value to measure the ratio of SNS and PNS. When the LF/HF ratio value more than 1, the SNS take part more; the ratio value equals to 1, SNS is as same as PNS; the ration value less than 1, the PNS take parts more (Godleski et al, 2000).

Figure 5 shows LF/HF value of each subject in the five songs which have been minus the initial value. The track order for higher proportion of parasympathetic is: 22, 21, 23, 25 and 24, however, the results just show a little difference in the patterns. Returning to the result of Fuzzy clustering method, Track 22 and 23 are belong to the best soothing group and the two songs also take top three in the higher proportion of parasympathetic order. It means that the clustering results not only match up the psychological response but also roughly correspond to the operation of physiological signals.

The result of questionnaires and fuzzy clustering algorithm are roughly matched up, even with the physiological consequence. As the second group shown in Figure 3, it fitted the expectations of this study: To identify appropriate music style as a therapeutic music which can make people stay in a soothing state. In earlier studies, most of them only focus on the classification of the music in physical properties such as: Signal wave, rhythm and frequency as the clustering basis. And the clustering methods are often used linear analysis, neural network and probability model, however, emotional vocabularies are usually vague and more subjective. Therefore, this study in addition to considering the amplitude, tempo and other objective factors, also using fuzzy relations function to convert the subjective feelings.

4. Conclusion

Using fuzzy c-mean clustering algorithm can make the result more fit in the expected emotional model, and the HRV related data could be a verification to test if subjects' mentality and physiology are consistent. This study initially understood the soothing music style has features with lower amplitude, slower tempo and is characterized by positive emotions.

In order to simplify the procedures of experiment, the study excluded diversified timbre in different musical instrument and assessed piano-based music. However, in reality, timbre may be an important factor to affect human's mood changes, and it must be carefully considered. The presenting way of music is diversified, in addition to the music features, the influence of external environment can be important as well. And it might also be associated with the player's performance skills or current mood. If above factors are taken into account, more resources would be incorporated in the analysis. Therefore, the environmental indicators, such as place, color, light and others can be added to the future research. Besides, in the ergonomics experiment, the outliers of the samples are too much, and we can just tell roughly situation of LF/HF data from the

average value in different songs. Therefore, the output signal of sensitive device need to be monitored carefully and the sample could be added more in future. In that way, the changing of physiological signals could be recognized clearly. Furthermore, the weight of each indicator of music is identical, however, some indicators may affect us more and some may affect less. As a result, the weight analysis or Analytic Hierarchy Process (AHP) could be added before clustering music styles in future research to get a more precise consequence.

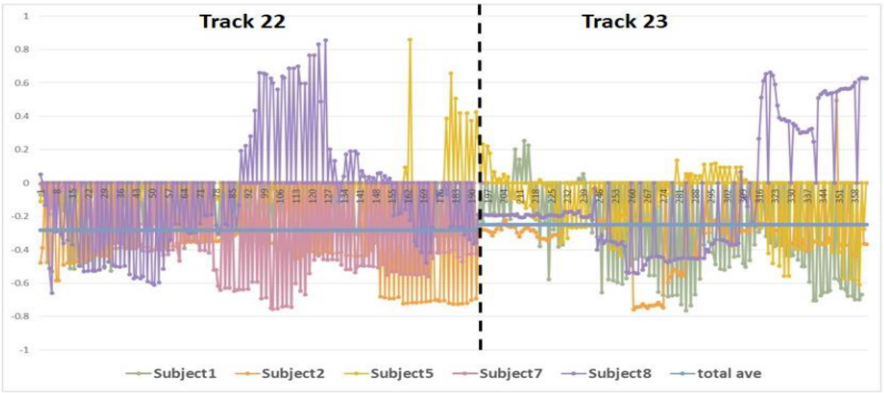

Figure 5. Each subject LF/HF value in Track 22& Track23 (have been minus the initial value)

In this research, the connection between subjected indicators and objective indicators provide a comprehensive survey on the arousal level of music toward people. Based on the result, an interactive response system can be contributed to select appropriate music for the use of therapeutic by physiological signals in specific situation. To sum up, this study gives a direction for composers or therapists to select appropriate music for therapeutic applications. Likewise, people can also find the songs which make their physiology and psychology relax equally and obtain a healthier life.

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