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3D Music Impact on Autonomic Nervous System Response and Its Potential Mechanism

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ABSTRACT

This paper is made to observe the impact of 3D (three-dimensional) and 2D (two-dimensional) music on autonomic nervous system and to explore the mechanism of the music. This study changes and retains some musical elements of the four music, and 73 healthy participants listened to four music tracks with headphones: 3D slow music, 2D slow music, 3D fast music, and 2D fast music. The results show that galvanic skin response (GSR) data decreased in all participants after listening to 3D music. Among them, the first and third 3D music, which bears obvious characteristics of sound spatial movements, high melody definition, stable rhythm structure, and high timbre identification of the main melody significantly changed participants' GSR compared to the benchmark obtained before the experiment (P<0.05). It can be reasonably argued that 3D music may improve the regulation of autonomic nervous system responses, which contributes to the health of mind and body.

KEYWORDS

3D Music, Autonomic Nervous Response Regulation, Binaural Audio, Music Therapy, Virtual Reality

INTRODUCTION

The constant pursuit of sound quality and effect is boosted by the development of virtual reality and computer technology, which makes mono and stereo audio obsolete. 3D (three-dimensional) audio has pointed to a new development direction for high-quality music. A variety of 3D audio technologies have emerged, immersing the audience in music and enriching the hearing experiences. This immersion opens doors to both psychotherapy and physiotherapy.

3D audio refers to a three-dimensional sound effect. It is also referred to as Virtual Acoustics, Binaural Audio or Spatialized Sound (Yin 2011). The sound effect is played back through speaker sets or headphones, creating an "illusion" of the sound. The virtual image is usually omnipresent in the three-dimensional virtual sound field, including the front and back, left and right, above and below. Compared to a sphere, the sound position of 3D audio contains two degrees of freedom: horizontal angle (front, back, left and right) and elevation angle (up and down). The core of 3D audio is altitude (up and down) information, unavailable in traditional stereo audio. Stereo audio refers to a two-dimensional sound effect, which only contains sound position from front to back, left and right.

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Music sometimes triggers people's emotions and physical reactions. Different types of music evoke different emotional reactions and reflect the regulation of the autonomic nervous system through physiological indicators, such as heart rate, galvanic skin response (GSR) and respiratory rate. In the field of music therapy, the healing function of music has been repeatedly proven in improving a patient's physical condition, training a particular skill or treating illness. Stimulative music and sedative music (Hodges, 2006) are considered to be the two most important relative factors that induce autonomic nervous responses. Since 1960, a large number of studies have begun to focus on the autonomic response of different types of music, for example, Krumhansl observed emotional and physiological changes caused by six classical music clips in 1996; in China, Sihua Li and Jingcheng Li selected active (heated, happy, nervous) and calming (quiet, sad, relaxed) music as materials, and found that active music can cause changes in the temperature, respiratory frequency and heart rate.

The application of stimulative 2D music and sedative 2D music mentioned above has been the mainstream of music therapy as a sound stimulating tool. 3D audio is only used in the auditory part of virtual reality therapy and the virtual environment perception of the blind (Ghali & Soliman, 2012).

Moreover, there are limited studies on the mechanism of music on the regulation of human autonomic nervous response, that is, how various elements of music affect human autonomic nervous response and regulation, such as the movement of sound in space (3D or 2D), melody, rhythm, and speed.

Therefore, in this study, some parameters of music stimulation on human body were established in a pioneering way, and on the basis of traditional music elements, sound space elements were added (for specific methods, please see below), and the regulation mechanism of music on human autonomic nervous system is speculated.

The human body's response to music is not only reflected in emotional and psychological aspects, but also in physiological indicators through the adjustment of the autonomic nervous system, such as changes in heart rate, skin electrical response, respiratory frequency and respiratory rate (Xie & Wang, 2011). This paper selected the physiological index of GSR to measure the differences in the physiological responses to different music.

MUSIC THERAPY AND VIRTUAL REALITY TECHNOLOGY

Music Therapy

Music therapy is a systematic intervention process in which the therapist uses various forms of musical experience, as well as the therapeutic relationship developed during the treatment process, to help the participant achieve a healthy goal. The music therapy process must include three factors: music, the participant being treated, and a specially trained music therapist (Gao, 2008). Music has long been used as an alternative method of treatment to relieve patients from anxiety symptoms (Bringman & Giesecke, 2009; Trappe, 2010). The positive role of music as a therapeutic modality for the treatment of preoperative anxiety has been well documented (Maureen & Bonnie, 1997; Karen & Lawrence, 2010). Moreover, meditation music as well as classical music may decrease stress levels and improve quality of life (Hall & Schmidt, 1999; Janet & Burke, 2007).

Application of Virtual Reality Technology in Clinical and Rehabilitation

Virtual reality technology is a computer simulation system that can create and experience virtual world. It uses computer to generate a simulation environment, which is a multi-source information fusion of interactive 3D dynamic visual and physical behavior of the system simulation, so that users are immersed in the environment. Virtual reality technology (VR) mainly includes simulation environment, perception, natural skills and sensing equipment. In medical science, the purpose of virtual reality is to reduce the harm caused by traditional medical treatments. Using new techniques and advanced treatment methods in a virtual way provides new possibilities to direct human body (Graur, 2014). For example, virtual reality exposure therapy is used as an alternative to traditional exposure therapy. There is now substantial literature investigating virtual reality exposure therapy (VRET) as a viable treatment option for anxiety disorders (Powers & Emmelkamp, 2008). In psychology, the application of virtual reality aims to bring an experience which transcends the current environment to the object. In addition, multi-sensory collaboration is considered to be the key to VR (Londero & Viaud-Delmon, 2010). In practice, VR therapy is biased towards visual immersion, but rarely focuses on hearing and in most cases ignores the hearing impact on participants in virtual reality therapy.

However, auditory sense plays an important role in virtual reality. Human ears are instrumental in judging distance, azimuth, space size. Firstly, people use spatial hearing to judge the direction and distance of the sound, such as assessing the size of the room and reacting to the dangers behind us. Secondly, the directional hearing allows us to concentrate on what we want to hear in a noisy environment. Furthermore, spatial hearing is closely related to our emotions. For example, a soft voice over the ears, representing our lover, makes us feel emotionally happy, and a tiger's roar brings a dangerous signal. People's perception of space is a primitive instinct, reflecting the human auditory needs. Although ordinary 2D stereo music is used as a basic audio material for music listening, it is disruptive in terms of sound localization and spatialization. In addition, it can cause confusion of listening. Therefore, sound should not be separated from the ontology in the virtual reality scene, but should be leveraged to strengthen or supplement the traditional VR therapy.

3D Sound and Music Therapy

Since 3D audio and ordinary 2D stereo audio have great differences in traditional auditory cognition, further research is required to explore how 3D audio triggers the physiological and psychological reactions. Compared to 2D stereo, 3D sound triggers the ear to judge the spatial position of the sound in real life scenes. Applying 3D music to music therapy can greatly restore the auditory state of the ears. Closed eyes would better to isolate external visual interference when 3D music is applied.

The differences in sound characteristics between 2D and 3D sounds are summarized below:

1. 3D and 2D sounds have differences in tone and volume.

By comparing the audio files of the two, it can be inferred that the 3D audio simulates the listening mode of the human ear. Part of the sound wave is diffracted and the other part is blocked to form the sound shadow (especially the sound wave outside the front direction). It causes a significant change in the frequency and volume of the sound wave. The human brain translates the frequency or volume change of the sound into position information, forming a more realistic positioning of the sound.

2. Compared to 2D sound, 3D sound restores more of the spatial information.

The 3D sound is better interpreted than the 2D sound to judge the space of a room. When the 3D sound source moves, the track is smoother. Although the 2D sound is more direct and cleaner, it only indicates a basic sound position and fails to stimulate spatial sense.

There are different methods to generate 3D audios. In this study, 3D audios are produced by applying 3D spatial localization technique to ordinary stereo audios through encoding techniques including HRTF function. The specific production method is detailed in the following paragraphs. As the output is in binaural format, it is only suitable for headphone listening.

PRODUCTION AND ANALYSIS OF EXPERIMENTAL MATERIALS

This paper conduct research on the basis of previous scholars' research. The materials are produced based on many factors. According to the principle that different types of music formed by different musical elements, the speed of music is taken as the control variable, and the stability of the rhythm structure, the clarity and recognizability of the main melody and the moving state of sound position associated with the latest 3D technology are taken as independent variables. The experiment selected music works from the "Earmersion" series, including two different types of slow music tracks (the speed is a quarter note equal to 50 per minute) and two different types of fast music tracks (the speed is a quarter note equal to 100-120 per minute).

The common feature of the two slow music tracks is the speed. The difference is the moving frequency, moving speed and moving range of the sound source position. Similarly, the two fast music tracks have the same speed and the difference is the moving frequency, moving speed and moving range of the sound source position. The four 3D electronic music tracks take into account are the Chinese people's musical beauty, music imagination, listening perception characteristics and overall sensibility, which means in the processing of harmony and melody, it is closer to the expression of traditional Chinese music.

The music duration is about two minutes each. The four 3D electronic music tracks are original, which exclude the influence of music preferences in the experiment and avoid the familiarity of the experimental music (Jiang, 2016).

3D Audio Production Method

The 3D audio materials used in the experiment are produced in DAW (Digital Audio Workstation) which supports multi-bus output. It includes three parts: composition, 3D location processing and binaural rendering. The sound field reconstruction plug-in to locate the sound in three dimensions, the plug-in setting the parameters of the room model and the binaural encoder are used to locate the sound in the virtual space to form the 3D sound effect.

The core principle of virtual 3D audio based on 3D sound localization technology is HRTF (Head Related Transfer Function), which contains the information of sound source points in 3D sound field. Using HRTF function, 3D sound field can be accurately reproduced (ZHANG & ABHAYAPALA, 2010). The formula of HRTF is shown in the Appendix.

Since HRTF changes with the position of human head and varies from individual to individual, the virtual 3D audio generated in this study takes into account the head shape of the majority and the basic environment. A more moderate HRTF is selected from Database for signal processing to avoid errors.

Musical Elements of the Four Pieces of Music

The specific musical elements of music are as follow:

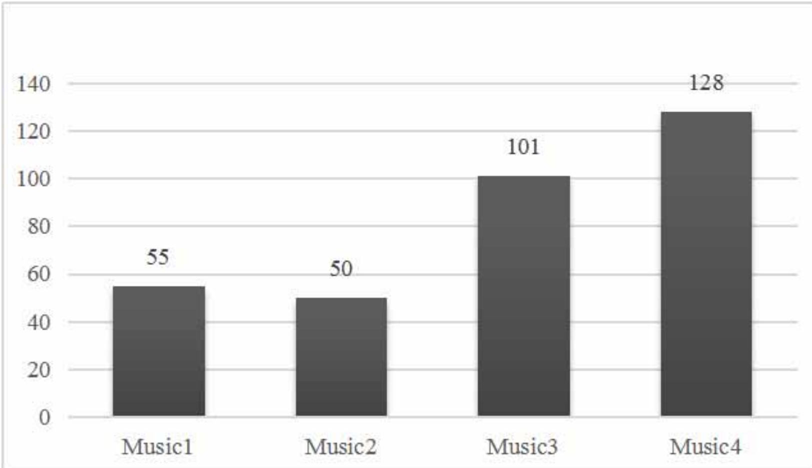
1. Speed

Speed (tempo) was measured in "beats per minute" (BPM). The tempos of music1 and music2 were 50bpm and 55bpm, both of which belong to Larghetto, corresponding to "sedative music"; music3 and music4 were 101bpm and 128bpm, both of which belong to Allegro, corresponding to "stimulus music." Thus, in the tempo variable, the four experimental music was controlled (Figure 1).

2. Stability of the rhythm structure (Zhang, 2007)

According to the degree of overlap between the rhythmical stress and the actual music stress, the author defined the stability of the rhythm structure, which reflects the significant degree of beat stress and was measured as a percentage. The formula was: the stability of the rhythm structure= the proportion of the stress on the first syllable (0-70%)+ the degree of clearness of the stress attack

Figure 1. Speed(tempo) of four pieces of music



and the degree of interference of other factors (0-30%). The result showed that the rhythm structure stability of music1 was 75%, music2 was 10%, music3 was 100%, and music4 was 69% (Table 1).

3. Moving frequency of sound position

This study tried to describe the moving frequency of the sound position according to changes in spatial position in music. The moving frequency of the sound position reflected the 3D sound effect of a music piece, and the effect of the sound spatial movement. The moving frequency of the sound position was measured in percentage. The formula was: the moving frequency of the sound source position = the moving range of the sound position/ the duration of the music. It can be calculated that the moving frequency of the sound position of music1 was 80%, music2 was 0, music3 was 100%, and music4 was 0 (Table 1).

4. Moving speed of the sound position

The moving speed of the sound position was measured based on the spatial change of the sound position per unit time in the music. The formula was: the moving speed of the sound position = the sound position shifting range/ duration of the music. It can be calculated that the moving speed of the sound position of music1 was 36(°/s), music2 was 0%, music3 was 60(°/s), and music4 was 0% (Table 1).

5. Moving range of the sound position

The moving range of the sound position was described by the spatial maximum angle of the sound position in the music. The moving range of the sound position of music1 was 360°, music2 was 0°, music3 was 360°, and music4 was 0° (Table 1).

6. Harmonious degree

According to the proportion of the number of harmonious chords in the piece of music, this study distinguished the difference among the four pieces of music in harmony. As shown in the TABLE1, the harmonious proportion of the four pieces of music was 90%, 60%, 90% and 90% respectively (Table 1).

7. Rhythm density

In addition to BPM, the rhythm density of the major notes in the music also plays an important role in listeners' perception of the rhythm. Therefore, the author tried the following aspects: according to the beats of each piece of music, the basic speed was divided by '4 divided by the duration of the note'. Music1 was mainly composed of quarter notes, so the rhythm density was 55/(4 /4) = 55; music2 was mainly composed of whole notes, the rhythm density was 50/(4/1) = 12.5; music3 was mainly composed of eighth notes, the rhythm density was 128/(4/8) = 256; music4 was also composed of eighth notes, the rhythm density was 101/(4/8)=202. This data was based on the speed value, which may further reflect the listener's sense of speed (Table 1).

8. Mode

In this study, music1 was a minor, music2 was e minor. Music3 was G major, music4 was c minor. In the scale, 1 represents minor and 2 represents major. Music 1, 2, 4 was minor, music 3 was major (Table 1).

9. Clarity of the main melody

This study described the clarity of main melody based on the definition degree of the main melody lines in the music, measured by percentage. The main melody of music1 and music3 was more obvious, with the clarity being 90% and 100%, and the main melody of music2 and music4 was more nebulous, the calculation was 10% and 30%, respectively (Table 1).

10. Clarity of the main melody timbre

According to whether the timbre used by the main melody in the music can be clearly differentiate, this study described the clarity of the main melody timbre,which was measured in percentage. Music1 has obvious melody lines and the piano timbre is clear, and the clarity of the main melody timbre is 70%. In the second piece, the melody is not very clear due to the fuzzy processing of the sound attack, which is 30%. The main melody of the third piece is is stronger and much more prominent than other timbre, the clarity of timbre is 80%. The main melody of the fourth piece is not clear, and the clarity of timbre is 40% (Table 1).

Music Feature Comparison

1. Music1 and Music2

Music1 and Music2 form a set of contrast groups. What is in common is the same Larghetto speed, the similar harmony based on the pentatonic tone and the similar frequency range at 20-4KHZ. The difference is that music1 is 3D and music2 is 2D, the sound in music1 moves in 3D space, which produces 3D sound effect, and the sound is distributed in the whole sound field. And the rhythm structure is more stable, the main melody is clear, and the main melody timbre can be identified. Music2 has no 3D sound effect, there is no movement of the sound position and the sound is distributed

Table 1. Musical elements of four music

	Speed	Stability of the rhythm structure	Moving frequency of sound position	Moving speed of the sound position (°/s)	Moving range of the sound position (°)	Harmonious degree	Rhythm density	Mode	Clarity of the main melody	Clarity of the main melody timbre
Music 1	55	75%	80.00%	36	360	90%	55	1	90%	70%
Music 2	50	10%	0.00%	0	0	60%	12.5	1	10%	30%
Music 3	101	100%	100.00%	60	360	90%	256	2	100%	80%
Music 4	128	69%	0.00%	0	0	90%	202	1	30%	40%

in the left and right channels. Compared with music1, the rhythm structure is unstable, the main melody is not clear, and the main melody timbre is difficult to identify (Table 2).

2. Music3 and Music4

Music3 and Music4 form a set of contrast groups. What they have in common is the Allegro speed, the similar harmony based on the minor tone and the similar frequency range at 20-20KHZ. The difference is music 3 is 3D and music 4 is 2D. The sound in music3 moves in 3D space which produces 3D sound effect and the sound is distributed in the whole sound field. And the rhythm structure is more stable, the main melody is clear, and the main melody timbre can be identified. Music4 has no 3D sound effect, there is no movement of the sound position and the sound is distributed in the left and right channels. Compared with music3, the rhythm structure is unstable, the main melody is not clear, and the main melody timbre is difficult to identify (Table 2).

PARTICIPANTS AND METHODS

Participants

The experiment was conducted during Popular Science Products EXPO in August 2017. Visitors to the Shanghai convention and exhibition center entered the laboratory in turn to participate in the experiment. 73 participants took part in the experiment. It was a random sample set with different genders, ages and professions. During the experiment, we control the environment sound volume to reduce the disturbing environment impact on the experimental results.

Table 2. Comparison of the four pieces of music

	Harmony	Frequency Range	Tempo	3D effect	Stability of the rhythm structure	Clarity of the main melody	Clarity of the main melody timbre
Music 1 & Music 2	similar	similar	similar	different	different	different	different
Music 3 & Music 4	similar	similar	similar	different	different	different	different

Among the 73 people, there were 30 males and 43 females. There was one person under 12 years old, six persons aged 13-18, sixteen persons aged 19-28, ten persons aged 29-40, six persons 41-50, sixteen persons aged 51-66, eighteen aged 66 or over. There were seven junior middle school graduates or below, ten high school graduates, eleven junior college graduates, 33 with bachelor degrees, and twelve with postgraduate degrees or over. There were ten educators, thirteen engineers and technicians, two art workers, ten in financial industry, twelve students, nine civil servants, and seventeen other occupations.

Participants were assigned to different experimental groups for cross listening. The first group consisted of twenty participants; the second group consisted of sixteen participants; the third group consisted of 22 participants, but the data of three participants of the first music are deleted due to errors; the fourth group consisted of fifteen participants (Table 3).

Table 3. The order of four music

	First Music	Second Music
Group 1	Music1	Music2
Group 2	Music2	Music1
Group 3	Music3	Music4
Group 4	Music4	Music3

Methods

1. Experiment Methods

Individuals were tested in sequence and all experiments included five steps: 1) the participants entered the experimental site; 2) lay down comfortably and put on the earphones, the testers introduced the experiment task and asked the participants to put on the skin electric reaction instrument; 3) listened to the pink noise. 4) listened to 3D electronic music. 5) the experiment finished. The testers thanked the participants and removed the skin electric reaction instruments. Experimental setting was in a semi-enclosed area with soft lighting and the best control of ambient noise.

2. Evaluation

Physiological indicators: measured the galvanic skin response data by instrument, and recorded the data before and after intervention.

3. Statistical analysis

The collected data were recorded into an Excel database and statistical analysis was performed by SPSS23.0 statistical software. Significant difference was set at $P < 0.05$ for all analysis.

RESULTS

Changes of GSR Data Before and After Four Music Intervention

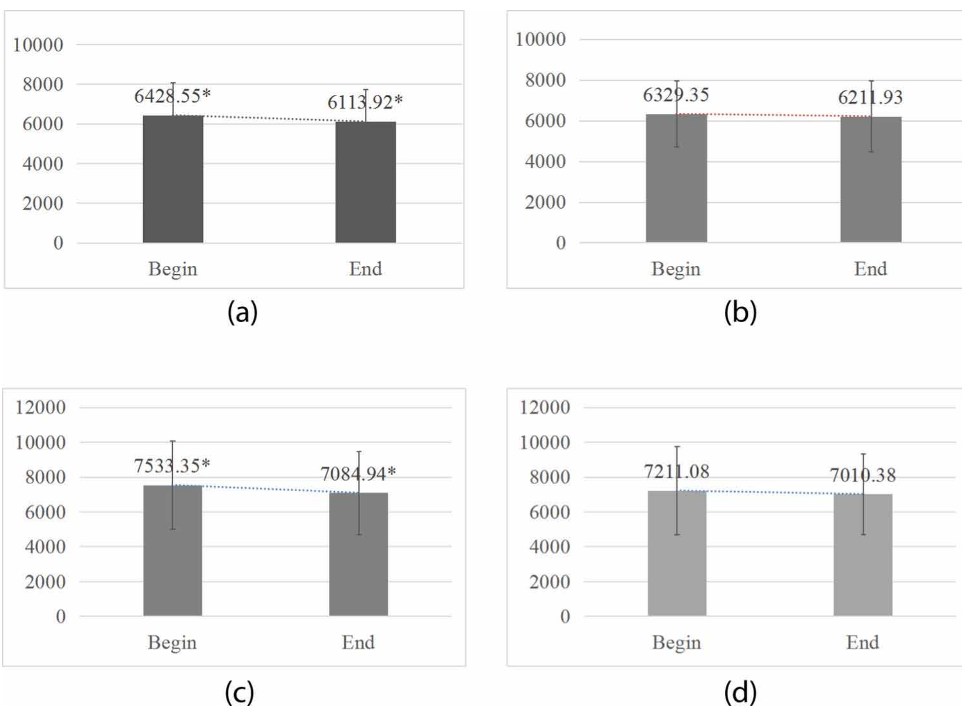
As shown in Table 4 and Figure 2, after the intervention of four music tracks, GSR signal was reduced comparing to that before intervention. The GSR data after music stimulation in music1 and music3 decreased more significantly which were both 3D music, and the difference was statistically significant ($P<0.05$). After the stimulation of music2 and music4 which were both 2D music, the GSR data showed a decreasing trend, but there was no significant difference ($P>0.05$). (Table 4 and Figure 2).

In the test, the GSR signals were declined before and after the intervention of 3D electron music, suggesting that 3D electronic music intervention has effect on the adjustment of autonomic nervous response, the reasons are discussed in the next chapter.

Table 4. Analysis on galvanic skin response data of four music

	Begin	End	T	P
Music 1	6428.55±1644	6113.92±1605	3.047	0.004*
Music 2	6329.35±1625	6211.93±1747	1.04	0.306
Music 3	7533.35±2543	7084.94±2402	3.095	0.004*
Music 4	7211.08±2541	7010.38±2327	1.217	0.232

Figure 2. a. Music1 GSR data b. Music2 GSR data c. Music3 GSR data d. Music4 GSR data



The Analysis of Musical Elements' Difference Between GSR Effective Group and Ineffective Group

In the above experiment, music1 and music3 had significant effect on the decrease of the GSR data, while music2 and music4 had less effect. Therefore, the author compared music elements in music1 and music3 (GSR effective group) with that music2 and music4 (GSR ineffective group). The results showed that GSR effective group and ineffective group have different and same musical elements to some extent. The more difference of some kinds of musical elements the music had, the more effect on GSR. After comparison, the effective degree of each element in the two groups of music for GSR skin electric response was ranked as follows. As shown in Table 5 and Figure 3, the moving frequency of the sound position, the moving speed of the sound position, the moving range of the sound position, the clarity of main melody, the stability of rhythmical structure, and the recognition degree of main melody timbre were the important factors in designing music to stimulate GSR. These factors have more difference between the GSR effective group and ineffective group relatively, indicating that these elements played an important role in regulating GSR.

Table 5. Ranking list of the effectiveness of each musical elements

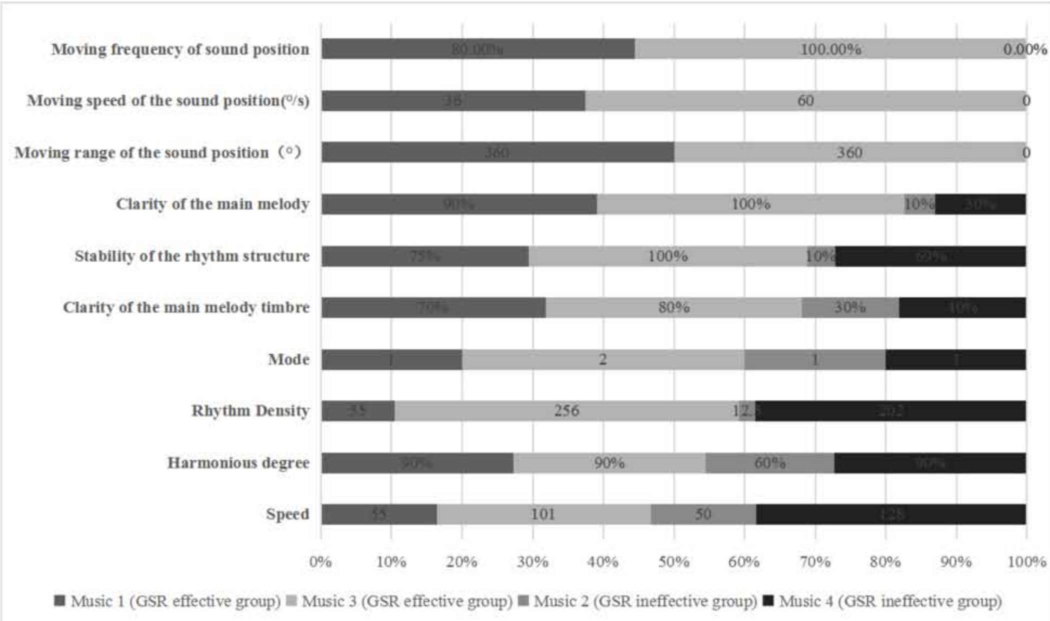
Ranking	Musical elements	Proportion of GSR effective group	Proportion of GSR ineffective group
1	Moving frequency of sound position	100.00%	0.00%
1	Moving speed of the sound position(°/s)	100.00%	0.00%
1	Moving range of the sound position(°)	100.00%	0.00%
4	Clarity of the main melody	82.61%	17.39%
5	Stability of the rhythm structure	68.85%	31.15%
6	Clarity of the main melody timbre	68.18%	31.82%
7	Mode	60.00%	40.00%
8	Rhythm density	59.18%	40.82%
9	Harmonious degree	54.55%	45.45%
10	Speed	46.71%	53.29%

DISCUSSION

Major Findings

The study shows that the galvanic skin response (GSR) can be used as an indirect indicator of sympathetic activity and can be used as an index to evaluate the emotional arousal level and some mental activity (Scheirer & Fernandez, 2002; Nasoz & Lisetti, 2003). Negative or high arousal stimuli were more likely to cause strong emotional response and increased GSR, whereas the positive or low arousal level of stimuli led to the decrease of the GSR of the participants (Tan & Li, 2012). In this study, GSR data of music1 and music3 decreased more significantly which were both 3D music. It can be inferred that 3D music may have a weakening effect on GSR as music1 and music3 are both

Figure 3. Comparison of musical elements between GSR effective group and ineffective group



3D music but the tempo is different. The tempos of music1 and music2 are basically the same, but the GSR data are different, the tempos of music3 and music4 are substantially the same, and the GSR data are different.

Music have been categorized into two groups for a long time: sedative music and stimulate music according to music emotional arousal level. The sedative music has the characteristics of "slow speed, low volume and weak rhythm", while stimulate music has the characteristics of "fast speed, high volume and strong rhythm". Our results showed that the speed and rhythm characteristics of these two types are disrupted in physiological response. Fast music did not all play a stimulating role, slow music did not all play a sedative role. For example, after the intervention of four music segments, the tempo of the first music and the third music was slow and fast respectively, which indicated that both fast and slow music had the same sedative effect. On the other hand, the tempo of first and second music was the same basically, but the GSR was different; the tempo of the third and fourth music was the same basically, but the GSR was also different. This shows that the speed characteristics cannot be simply used to correspond to sedation or stimulation.

In music, people's feeling about speed may also be related to the rhythm density. For example, in the sense of hearing, listeners will have the similar feeling with fast and slow rhythm from two works when they listen to a lot of eighth notes in 50bpm music and 100bpm music with only quarter notes. The speed of music is closely related to the rhythm density. If we only begin with the speed of music to study the effect of fast and slow music on music decompression, it will let the listener have similar feelings to two works with fast and slow rhythm. It does not really achieve the purpose of clear classification. In order to rigorously explore the influence of speed on the regulation of autonomic nervous response in the population, we considered and set the rhythm density as a parameter. In the GSR effective group, the value of the first music was 55, and the third was 256, although the values were completely different, the change of the GSR stimulated by both the first and third music was significant before and after the intervention ($P<0.05$). it confirms people's feeling of speed is not simply corresponding to two physiological responses for stimulate or sedation.

Therefore, in physiology, it is not because of stimulating music (fast speed) that certain stimulating effect will be produced; sedative music (slow speed) must produce sedative effect. The classification of stimulating music and sedative music is questionable.

This study believed that physiological responses induced by music are affected by a variety of musical elements and their interaction. The specific musical elements and their combinations are an important factors of human physiological responses. In this study, the stability of of the rhythm structure, the space moving state of sound position, and the recognition of main melody have the greatest influence on the regulation of autonomic nervous responses.

1. The 3D effect of sound in music.

The 3D space movement of the sound is evolved with the development of digital audio technology. Therefore, there is almost no literature in this area. This study used this new technology in music1 and music3. In this experiment, we found whether the position of sound is moving in music, that is, the spatial movement frequency, speed, range of the sound position, are the most effective factors in all music elements, up to 100%. That is to say, these three factors had the most obvious difference between the GSR effective group and the ineffective group. This indicates whether the spatial position of the sound is moving in space has a greater effect on the regulation of human automatic nervous response, and it also shows that the ordinary people are more sensitive to spatial changes in music. It can be speculated that the 3D spatial movement of sound in music can make the listener pay more attention to the music they hear, track the detailed changes of music, so as to better transfer distractions and regulate the autonomic nervous system.

2. Melody definition and timbre identification of the main melody.

The main melody clarity ranks the fourth in all music elements, which is 82.61%, and the timbre identification of the main melody ranks sixth, which is 68.18%, and effect is relatively high. Both these two indicators are about the clarity of the main melody. This indicates that the clearer the main melody of music is, the greater the autonomic nerve modulation influences. “The familiar environment can make people feel safe and controllable”. Similarly, familiar music can also make people feel safe and controllable (McCaffrey & Good, 2000), thus achieving the goal of relaxation. In this experiment, music with clear melody and easier to distinguish timbre produced a sense of familiarity and reduced GSR.

3. Stability of the rhythm structure.

The effectiveness of the stability of the rhythm structure in all music elements ranks the fifth place, at 68.85%. As Darwin wrote in his second volume ofthe Original of Human Being, “this is not an appreciation, or at least an awareness of the musical ability of the beat and the rhythm seems to be peculiar to all animals, and there is no doubt that it is determined by the general physiological nature of their nervous system” (Feng, 1984). This shows that human beings’ awareness or sensitivity to rhythm is an inborn ability. This also shows that music with strong stability of rhythm structure can cause more autonomic nervous response regulation.

Limitations

There are still some limitations in this study. In addition to the difference in the moving state of the sound source position, other variables such as melody and tone may lead to inaccurate results. In addition, the experimental objects of the four music tracks are different, hence the experimental results may be inaccurate due to individual differences.

CONCLUSION

This study examined the intervention effect of the 3D music on the automatic nervous response of the general population and explored the mechanism of the music. After listening to the four music, participants' GSR is decreased in all groups. Among them, the intervention with the first and third original 3D music which has obvious sound movement, high melody clarity of the main melody, stable rhythm structure and high timbre recognition of the main melody resulted in the significant change of GSR ($P<0.05$). This indicates that the 3D music has significant improvement effect on the people's autonomic nervous response regulation. In music, elements such as the speed, beat, stress, timbre, mode, harmony, the movement of sound position have different effects on the regulation of autonomic nervous response to the general population. Therefore, music parameters and their combinations affect human excitability and inhibition, which are important indicators of human physiological response. This study indicates that the stability of the rhythm structure, the movement state of the sound position, and the recognition of the main melody have an important influence on the regulation of human autonomic nervous response.

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APPENDIX: FREE FIELD, THE HRTF

In the case of free field, the HRTF of the left and right ears is defined as:

$$H_L = H_L(r,\theta,\varphi,f) = P_L(r,\theta,\varphi,f) / P_0(r,f) \quad (1)$$

The P_L, P_R represents the sound pressure of the left and right ears of the listener and P_0 is the sound pressure when the listener is not in the position. From formula (1), we can see that H_L and H_R are the functions of the horizontal angle θ, elevation angle φ, distance from the sound source to the center of the head r and the frequency f of the sound wave.

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