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Neural activation of different music styles during emotion-evoking

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Abstract

Music style is tightly connected with listeners' emotional processes and neural activities. However, it remains unclear how the brain works when different music styles are processed emotionally. The current study analyzed the neural activation associated with five music styles during emotion-evoking. Twenty non-musicians participated in the functional magnetic resonance imaging (fMRI) scanning and the emotional ratings of pleasure and arousal evoked by pop, rock, jazz, folk, and classical music. Results showed that classical music was associated with the highest pleasure rating and deactivation of the corpus callosum. Rock music was associated with the highest arousal rating and deactivation of the cingulate gyrus. Pop music activated the bilateral supplementary motor areas (SMA) and the superior temporal gyrus (STG) with moderate pleasure and arousal. As the first fMRI experiment investigating the relationship between the music style and emotion, it provides neural correlates of different music styles during emotion-evoking.

Keywords

music style, fMRI, evoked pleasure, evoked arousal, non-musicians

Whenever we talk about music, we will inevitably talk about music styles. Music style is a synthetical feature that combines modes, rhythm, timbre, melody, and other characteristics. Generally speaking, music style can be divided into classical and pop music (Yudkin, 2007). Classical music evolved from church music and is generally considered serious and of lasting value (Weber, 2005). Pop music is casual in content and structure, reflecting the

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daily life activities of the working people (Bennett, 2001). Specifically, the subgenres of pop music include country, rock, jazz, electronic music, and many other new styles. In the current era, which music penetrates human life extensively, pop, classical, rock, jazz, and folk music are the best-known music styles with differentiated emotional expressiveness and emotional regulation (Bhatti, Majid, Anwar, & Khan, 2016; Cook, Roy, & Welker, 2019; Kumaran, 2018; Lambe, 2017; Nanni, Costa, Lumini, Kim, & Baek, 2016; Schellenberg & von Scheve, 2012).

Different music styles arouse different emotions. Eerola (2011) analyzed nine separate datasets of various music styles and found the low generalizability among the styles for valence (16%) and moderately good generalizability among the styles for arousal (43%). Specifically, jazz and classical music were associated with longing, spirituality, and peacefulness; techno and Latin-American with disinhibition, excitement, and passion; and pop/rock with aggression, irritation, and revolt (Zentner, Grandjean, & Scherer, 2008). Even with positive lyrics, heavy metal and hip-hop music aroused more negative emotional responses than pop music in listeners (Susino & Schubert, 2019). However, the neural mechanisms of the different music styles were not clear during emotion-evoking.

Studies attempted to investigate the neural relationships between music styles and emotion by emotional regulation or fans' brain activities. Lu, Dai, Wu, and Qin (2012) found that classical music aroused the strongest alpha wave with the best effects in regulating sadness of various music styles. Strong activation of the alpha wave indicated psychophysiological relaxation (Fried, 1990), which provided a rational explanation of classical music's emotional effects. Ventral default mode network was tightly connected with multiple cognitive and emotional processes (Liu et al., 2018; Satpute & Lindquist, 2019). Classical musicians were found with stronger connectivity between ventral default mode network and frontal pole than non-classical musicians during music improvising (Belden et al., 2020), which implied classical music's advantage in emotion processing. In fans' studies, Sun, Zhang, Duan, Du, and Calhoun (2019) found classical music lovers and heavy metal music lovers had different resting-state functional connectivities and fractional amplitudes of low-frequency fluctuations. In Istók's (2013) study, a larger N1 amplitude was found in fans of Latin-American music than fans of heavy metal music when they listened to their preferred music, which was explained as different concomitant pleasant or unpleasant sensation because of two genres' brightness and roughness (Lartillot, Toiviainen, & Eerola, 2008). However, limited and indirect neurological evidence is inadequate to explain the role of different music styles in emotion-evoking.

To clarify the relationship between music style and its emotional effects, we conducted functional magnetic resonance imaging (fMRI) scans of participants' emotion-evoking when listening to different music styles. A post-MRI rating was carried out to measure listeners' pleasure and arousal. The first key point is to control the group variables and decrease additional interference, such as music preference, musical training, and age. Inclusion criteria included non-musicians, aged 18–25 years, to avoid interference from music training and age effect (Park et al., 2014; Vuilleumier & Trost, 2015). The second one is to select music styles that can evoke emotions spontaneously and effectively. Before the scan, we administered a preference survey of 18 music styles to a target sample of 500 people and identified the five most-preferred styles (pop, classical, rock, jazz, and folk music). The last one is to analyze the behavioral results and fMRI results to clarify the relationship between music styles and emotions. As the first fMRI study of the music styles' emotional processing, we hypothesized that different styles of music could evoke different brain activities and were associated with distinct pleasure and arousal.

Methods

Design

This study had a repeated measures design. All the participants listened to each music excerpt of the five styles during fMRI scanning and behavioral rating separately. The independent variable was musical style, and the dependent variables were behavioral evaluation and neural activity. The scores of emotional arousal and emotional pleasure for the five music styles were separately analyzed by one-way ANOVA. The neural results were analyzed by a one-way population-level ANOVA and the region of interest (ROI) analyses.

Participants

The study included 20 non-musicians (10 males), whose average age was 21.55 years (± 2.42). Participants completed an online open music perception test (http://www.brams.org/en/onlinetest/?Tdsourcetag=s_pcq_aiomsg), which was used for excluding individuals with amusia and published by the International Laboratory of Brain, Music, and Sound Research (University of Montreal and McGill University, Canada). No participants had MRI contraindications, including no metal implantation in vitro, no history of psychosis, no history of drug use, no space claustrophobia, no heart, and brain-related surgery, and were right-handed. Participants agreed to participate in the study and signed two informed consents for nuclear magnetic resonance experiments. This study was approved by the Ethics Committee of the Department of Psychology of Southwest University.

Materials

The experimental materials were musical excerpts of pop music (30 samples), rock music (30 samples), folk music (29 samples), jazz music (10 samples), and classical music (17 samples). Each musical sample played about 2–12 s.

The above 116 songs were selected from 1,000 songs with high quality, which were downloaded from seven widely used music apps in China. The 1,000 songs were chosen to cover 18 music styles (pop, R&B, rock, hip-hop, jazz, blues, electronic, metal, country, folk, classical, world music, new age music, light music, reggae music, symphony, punk, and ACG [Animation, Comic, Game]). Then, a music style preference survey of a target sample of 500 people showed that pop, classical, rock, jazz, and folk music were their preferred music among 18 styles. Then 30 songs were chosen in each style. Five musicians clipped each song and preserved a 2–12 s sample with the complete semantic information. All samples faded in and out of each piece of music for .5 s, to meet the requirements of the E-Prime 2.0 system for soundtrack parameters to play.

Seventeen non-musicians were invited to assess the 150 samples in familiarity and sound quality. All evaluators ranged in age from 18 to 25 years (mean age 21.45 ± 2.67). During the evaluation period, each rater scored 150 samples for familiarity and sound quality on a 7-point (1 = *very unfamiliar* and *poor sound quality*, 7 = *very familiar* and *high sound quality*) scale using Dell computers and headphones in a private and quiet room. All the excerpts were played at an intensity of 60 decibels during the whole evaluation process. Finally, 116 songs with an average familiarity of 4.71 (± 2.15) were selected as materials for this experiment because their familiarity was within one standard deviation and their sound qualities were higher than 5. The specific familiarity distribution is shown in Figure 1. Also, the experimental material contained a 1-s detection stimulus that repeated a "beep, beep, beep" alarm sound.

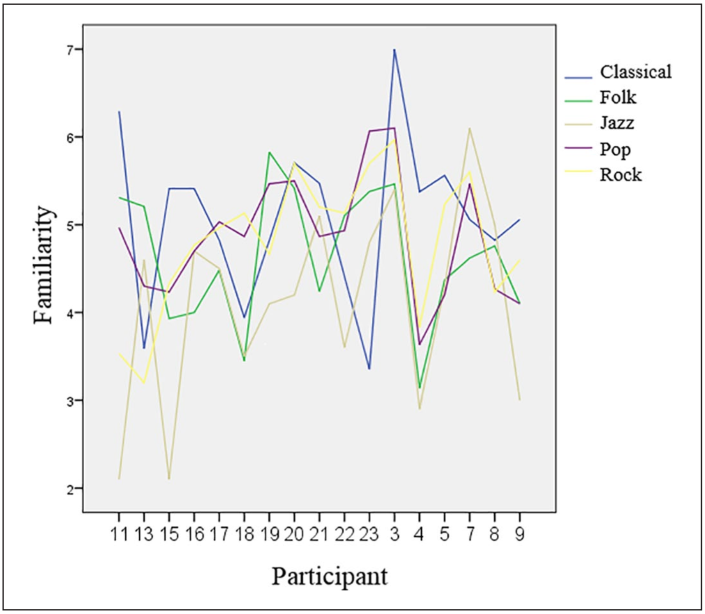

Figure 1. Familiarity of Five Kinds of Music.

Procedures

The first part was the practice stage. In the beginning, the State-Trait Anxiety Scale was used to evaluate participants' emotional state. Subsequently, participants practiced in a passive listening paradigm with the instruction:

> You will hear some music lasting for 2–12 s. Please stay relaxed and concentrate on the music played in the experiment, and feel the emotional experience brought by the music. During the listening, you are required to respond to random alarm "beep" sound by keystrokes.

This alarm can avoid listeners' distractions or sleeping during emotion-evoking. The last part of the practice was playing peaceful music. This stage was about 10 min.

The second part was the formal fMRI experience. The task consisted of three blocks and two breaks. Each block contained 35–40 songs. Five styles of music (pop, classical, jazz, folk, and rock) were pseudo-randomly distributed throughout each block. Each participant entered the nuclear magnetic resonance laboratory and completed the emotional experience during both waking and eye-closed states. Each music sample was played twice. Each participant then rested for 4 s before playing the next music sample. Before each block, the following instructions were given: "Please close your eyes, keep your head still, relax and concentrate on feeling the emotion brought by the music. During the listening, you are required to respond to a random 'beep' sound by keystrokes." The rest time between the two blocks was determined by each participant and ranged from 10 to 30 s. This part lasted about 40 min (Figure 2).

The third part was an emotional assessment task. After leaving the nuclear magnetic resonance laboratory, participants rested 1–3 hr and then entered the behavioral laboratory to assess feelings of pleasure and arousal associated with the same 116 music samples (Figure 3). At the end of the study, the State-Trait Anxiety Questionnaire scores were collected again.

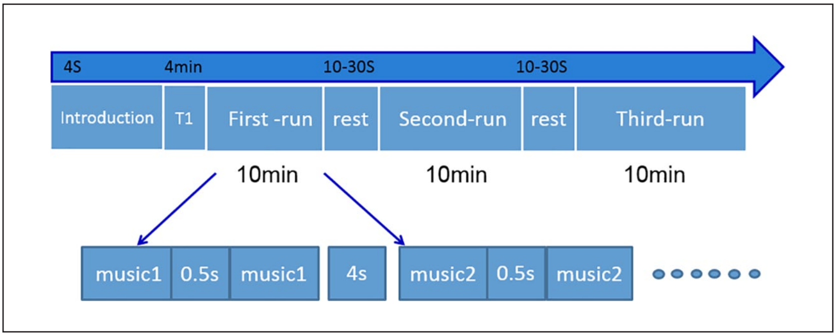

Figure 2. fMRI Scanning Procedure.

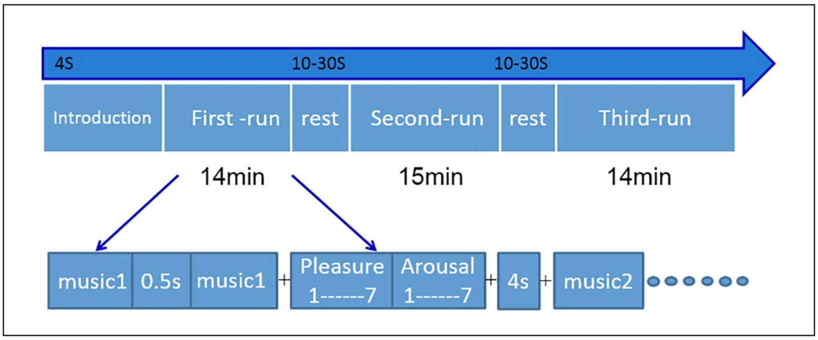

Figure 3. Behavioral Rating Procedure.

The stimulus presentation during the scanning process was performed using the E-Prime 2.0 program on Dell computers. Bilateral auditory stimulation is a customized noise reduction system that can attenuate noise by about 28 decibels during fMRI scanning. During the scanning period, the loudness of the music presented to the participants was about 98 decibels. After hearing loss with noise reduction system headphones for, the auditory stimulus was about 70 decibels in the participants' ears.

Behavior data analysis

We analyzed the State-Trait Anxiety Scale scores pre- and post-MRIs to ensure that participants in the experiment had no abnormal emotional states. We collected measures of perceived pleasure and arousal from 20 participants as they listened to 116 music samples. According to the analysis of brain image pretreatment, three persons whose head movement value exceeded 2.5 mm were excluded from the brain image analyses. The experimental data of 17 persons (nine males) were retained to carry out a one-sample ANOVA.

Brain imaging data analysis

Brain image data in this study were collected using Siemens Magnetom Trio Tim (Germany Erlangen) 3T scanner. The planar echo imaging sequence was used to collect and record

T2-weighted images ($TE = 30$ ms; $TR = 2{,}000$ ms; flip angle = 90 degrees, field of view [fov] = 220 mm ×× 220 mm; matrix size = 64 × 64; 32 slices of 3 mm thick brain images were collected at one whole-brain scan interval; in-plane resolution = 3.4 mm × 3.4 mm; interlayer jump = .99 mm. A total of 176 images with T1 weights were collected in a whole-brain scan. The thickness was 1 mm and the plane resolution was .98 mm × .98 mm ($TR = 1{,}900$ ms; $TE = 2.52$ ms; flip angle = 90 degrees; field of view [fov] = 250 mm × 250 mm. The study used SPM8 (Welcome Department of Cognitive Neurology, London, United Kingdom) to analyze the brain function images. The sequence of brain image slices was corrected by slice timing correction, and the data are re-estimated and modified after standardization. To collect the steady-state images in the process of scanning, the first ten images of each scan were deleted in data analysis. The image is standardized by the Montreal Neurological Institute space to register the voxel size of the image to 3 mm × 3 mm × 3 mm, and then smoothed using a Gaussian kernel. The maximum half-width of the smooth nucleus was 6 mm × 6 mm × 6 mm.

All data processing was completed in Matlab 2015b and SPM 8. First, we used Dparsf software to preprocess the data, including standardization, spatial registration, and smoothing. After pretreatment, we obtained data for six head movements, and the data of participants whose head movements exceeded 2.5 mm were excluded. In this study, the data of three participants were excluded because their head movement values were greater than 2.5 mm. The valid data of 17 participants were reserved for further analysis. Second, we carried out an individual-level analysis. This part defined six sequences: pop, rock, folk, jazz, classical, and the exploratory response to “beep.” The time point of the data was the presentation time of each musical excerpt. Finally, we performed a one-way population-level ANOVA. The threshold of false discovery rate (FDR) correction ($p = .05$) and voxel size ⩾ 20 was chosen to determine whether there were significant differences in each music group.

Analyses focused on the relationship between temporal cortex and emotion areas BOLD signal. In addition to the voxel-wise analysis, we also performed ROI analyses for six areas of interest (left and right STG, posterior cingulate gyrus, and amygdala). Mean (*SD*) Talairach coordinates of the ROIs are $x = \pm 52$ (5), $y = -12$ (4), and $z = 3$ (5) for the STG, $x = 0$ (10), $y = -24$ (6), and $z = 20$ (7) for the posterior cingulate gyrus, and $x = \pm 22$ (5), $y = -6$ (4), and $z = -14$ (5) for the amygdala. We chose ROIs that have been implicated in previous studies of music-evoked emotion.

Results

Behavioral results

First, the State-Trait Anxiety Scale scores were analyzed. The mean trait anxiety score for 20 participants was 52.55 (± 3.33, range: 46–58). Referring to the revised results of the norm of the State-Trait Anxiety Scale for Chinese College students (45.31 ± 11.99; Li & Qian, 1995), it can be judged that there was no anxiety trait present in this sample. There was no significant difference ($p = .19$) in the anxiety state scores between pre- (51.25 ± 3.35) and post-tests (52.50 ± 2.44).

Second, the scores of emotional arousal and emotional pleasure for the five music styles were separately analyzed by one-way ANOVA (Table 1). In the dimension of pleasure, $F(4, 1966) = 17.36$, $p < .01$, $Eta^2 = .03$, $M_{classical}$ (4.62 ± .08) > M_{pop} (4.33 ± .06) > M_{folk} (4.23 ± .06) > M_{jazz} (4.18 ± .11; $p < .01$), M_{rock} (4.43 ± .06) > M_{folk} (4.23 ± .06; $p < .01$; Figure 4). In the arousal dimension, $F(4, 1966) = 17.36$, $p < .01$, $Eta^2 = .03$, M_{rock}

Table 1. Results of the behavioral ANOVAs.

Dimension	Mean scores			Mean scores
Pleasure				
Class	4.62 ± .08	>	Pop	4.33 ± .06
Rock	4.43 ± .06	>	Pop	4.23 ± .06
Pop	4.33 ± .06	>	Folk	4.23 ± .06
Folk	4.23 ± .06	>	Jazz	4.18 ± .11
Arousal				
Rock	4.96 ± .07	>	Pop	4.62 ± .07
Pop	4.62 ± .07	>	Folk	4.28 ± .07
Pop	4.62 ± .07	>	Jazz	4.18 ± .11

ANOVA: analysis of variance.
All differences were significant at the .01 level.

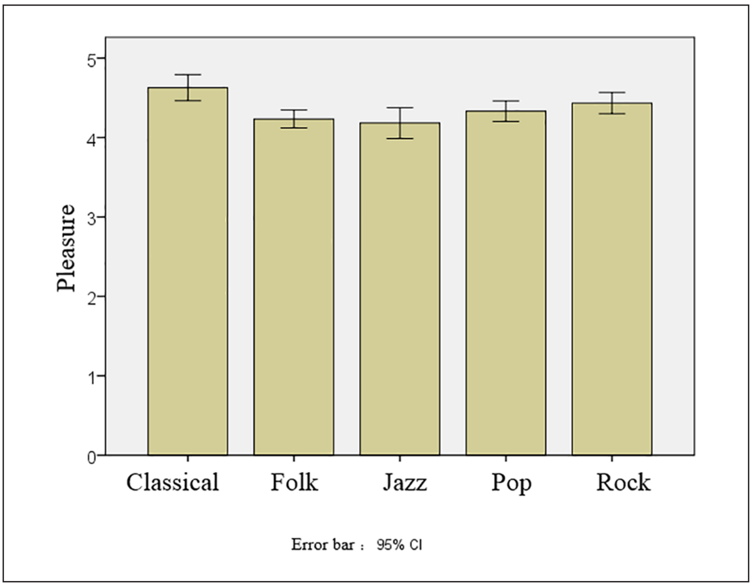

Figure 4. Pleasure Ratings for Five Music Styles.

(4.96 ± .07) > M_{pop} (4.62 ± .07) > M_{folk} (4.28 ± .07; $p < .01$), M_{pop} (4.62 ± .07) > M_{jazz} (4.18 ± .11; $p < .01$; Figure 5).

No difference was found when analyzing gender in two dimensions.

fMRI results

In the analysis of brain activation results, FDR correction with $p = .05$, and voxel value over 20 were selected. Pop music activated the bilateral supplementary motor areas (SMA) and bilateral temporal gyrus (Figure 6). Rock music deactivated the bilateral cingulate gyrus (Figure 7). A paired sample *t*-test of different styles of music showed that pop music produced significantly stronger activation of the bilateral superior temporal gyrus (STG) and

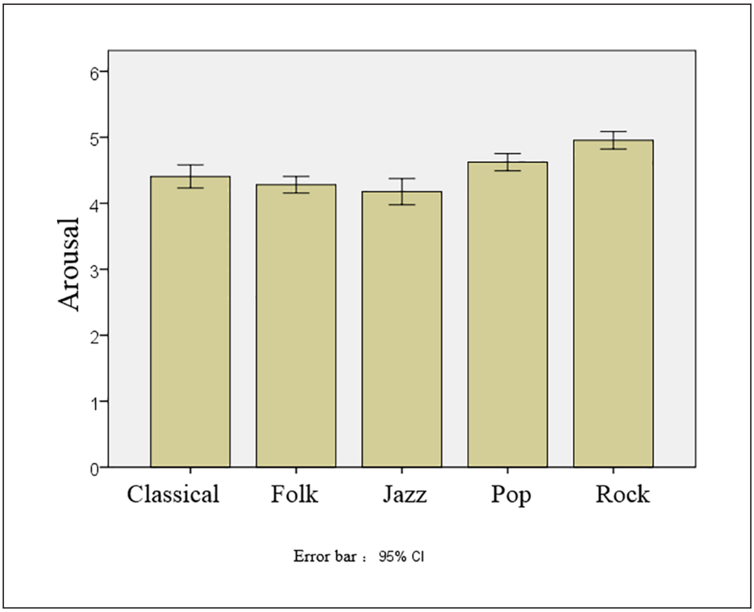

Figure 5. Arousal Ratings for Five Music Styles.

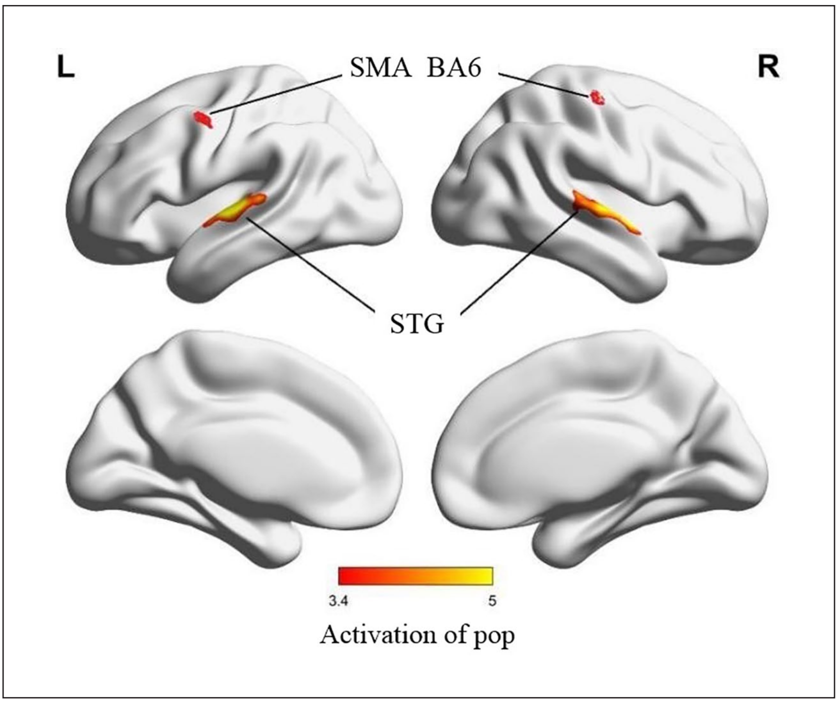

Figure 6. The Activation of Pop Music.

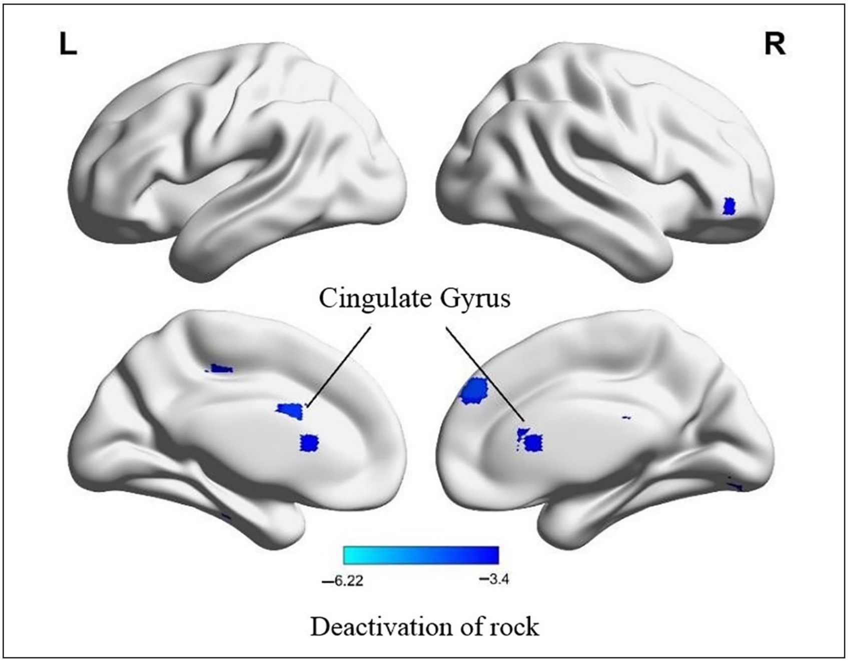

Figure 7. The Deactivation of Rock Music.

Table 2. Activation of different music styles.

Condition	Area	Cluster size	Peak Z	x	y	z
Activation of pop music	STG	236	6.16	–51	–12	3
	SMA	34	6.13	–51	–3	54
Deactivation of classical	Corpus callosum	38	5.15	0	15	9
Deactivation of rock	Cingulate gyrus	911	5.56	–21	–30	42
	Cingulate gyrus	353	4.77	9	–3	21
	Cerebellum	199	4.69	–33	–72	–27
	Inferior temporal gyrus	20	4.27	–45	–42	–6
Pop–classical	SMA	30	5.78	–51	–3	54
	Temporal lobe	172	5.66	–51	–12	3
	MTG	157	4.79	57	–3	–3
Folk music–rock music	Cerebellum	45	4.81	–33	–72	–27
	Sub-gyral	49	4.60	–21	–30	42

STG: superior temporal gyrus; SMA: supplementary motor areas; MTG: middle temporal gyrus.

bilateral SMA compared with classical music, while folk music produced significantly stronger activation of the left cerebellum, left occipital lobe, and left sub-gyral region than rock music (Tables 1 and 2).

When analyzing the correlation between the emotional ratings and the fMRI activation in ROIs (STG, cingulate gyrus, and amygdala), no significant results were found in the internal relationship between brain regions ($p > .05$) and the external relationship between brain regions and behavioral data ($p > .05$).

No neural difference was found when analyzing gender in a full-factor ANOVA.

Discussion

As the first study investigating the neural activation of different music styles during emotion-evoking, we analyzed the pleasure and arousal elicited by five music styles and sought to determine the neural connection between music styles and listeners' emotional processing. Behaviorally, classical music was associated with the highest pleasure. Rock music showed the highest arousal. Pop music activated moderated pleasure and arousal. Neurological evidence suggested that pop music mainly activated the bilateral temporal gyrus and bilateral SMA, while rock and classical music showed deactivation in the cingulate gyrus and corpus callosum, respectively. Overall, with different brain activation in the auditory cortex, sensorimotor cortex, and limbic system, different music styles play various roles during emotion-evoking.

Classical music

Classical music is a style labeled with emotions like comfort, profound, plentiful, and affectionate (Gerdner, 2000; Johnson, 2002; Scheufele, 2000). Behaviorally, classical music provided positive emotional effects on increasing participants' feelings of ease (Rea, MacDonald, & Carnes, 2012). On fMRI, classical music appeared to deactivate the corpus callosum in this study. The corpus callosum is a critical brain structure providing the bilateral link in the processing of emotion, especially for emotional arousal (Gerdner, 2000; Paul et al., 2006; Shobe, 2014). Combining with classical music's suppression of emotions and impulsive behavior, the deactivated corpus callosum here may be the neural substrate of classical music's inhibition of emotional arousal and impulsive behavior controlling. In imagined steak restaurants, people chose classical music to achieve their low arousal emotion desire (tendernes; Kontukoski, Paakki, Thureson, Uimonen, & Hopia, 2016). Anti-crime music experiments found that piping classical music into a crime-ridden area (The London Underground) decreased robbery by 33%, staff assaults by 25%, and vandalism by 37% (Capers, 2009). Arousal and valence are two relatively independent dimensions in emotional processing (Baumgartner, Willi, & Jäncke, 2007). Although classical music had an advantage in pleasure evoking, it can also suppress listeners' evoked arousal, which was supported by the deactivated corpus callosum.

Rock music

Rock music is a style with the terms violent, brave, freedom, and destructive, whose strong emotional arousal was tightly connected with strong skin resistance, high breathing rate, and heart rate (Hoyt, 2004; Tachibana, Noah, Ono, Taguchi, & Ueda, 2019; Wilson & Aiken, 1977). In the current study, the highest arousal of rock music was consistent with its high energy in musical expression and emotional arousal (Cook et al., 2019; Coyne & Padilla-Walker, 2015; Rentfrow & Gosling, 2003). Meanwhile, fMRI results showed that rock music deactivated the bilateral cingulate gyrus, left cerebellum, and left inferior temporal gyrus. The cingulate gyrus is an integral part of human emotional, functional circuits (Koelsch, 2014), and participates in emotional and self-evaluation processes. Chan et al. (2016) found deactivation in the cingulate gyrus during facial processing in young individuals with early depression. Depending on rock music's spirit of rebellion and resistance in young people (Baker, 2005; Straw, 1984) and the negative affection in lyrics (Brattico et al., 2011), the deactivation of cingulate gyrus here can be an evidence to explain the negative effect on emotional pleasure in rock music.

In musical activities, the inferior temporal gyrus was an important area participating in multi-modal processing (Zatorre, Perry, Beckett, Westbury, & Evans, 1998), especially in processing emotion combining with picture and music (Baumgartner, Lutz, Schmidt, & Jäncke, 2006; Burkhard, Elmer, & Jäncke, 2019; Loui, Zamm, & Schlaug, 2012). In the current study, the deactivated inferior temporal gyrus may be the result of the eye-closed state, which restrained participants' multi-modal processing. In addition, all the listeners were required to be motionless during fMRI scanning. The left cerebellum, once an active area in moving to music (Schaefer, Morcom, Roberts, & Overy, 2014), was deactivated under the condition of restricted movement. Its deactivation here reflected the process conflict of an awakening of rock music and inhibition of physical activities. Combining the deactivation of inferior temporal gyrus, it may be that the emotion processing of rock music was more susceptible to the external environment.

Pop music

Pop music was of moderate pleasure and arousal with significant activation in the bilateral STG, and bilateral SMA. STG and SMA were significant neural areas in auditory arousal (Angulo-Perkins et al., 2014), pleasant emotional experience (Bogert et al., 2016), and motor arousal function (Grahn & Brett, 2007). Compared with classical music, pop music also showed stronger activation in the bilateral temporal area, right middle temporal gyrus (MTG), and left SMA. STG is the core area for auditory information processing and is tightly connected with human's music emotion (Bogert et al., 2016; Koelsch, Rohrmeier, Torrecuso, & Jentschke, 2013; Park et al., 2014). SMA is essential for brain areas involved in music performance, music appreciation, and music imagination (Bangert & Altenmüller, 2003; Baumann, Koeneke, Meyer, Lutz, & Jäncke, 2005; Zatorre, Chen, & Penhune, 2007). As pop music was found to be simple, repetitive and highly predictable, the neural activation of auditory perception and sensorimotor here indicated that pop music were easier to arousal imagination or expectation with robust detection of the mental states of the listeners (Treder, Purwins, Miklody, Sturm, & Blankertz, 2014).

In the current study, pop music was presented originally with lyrics and activated stronger right MTG than classical music. Right MTG is related to the processing of semantic aspects of language (Hickok & Poeppel, 2007), and music-evoked emotion by expressed affect (Steinbeis & Koelsch, 2008). Its stronger activation here can be an evidence of pop music's lyrics advantage in activating semantic understanding and promoting emotional expression. However, why does pop music, only with moderate emotional valence and arousal, activate the strongest brain activity? Krumhansl (2017) carried out a study that spanned a century of popular music, divided into ten decades, with participants born between 1940 and 1999. He found that pop music was rated as the most popular music by people of all ages. Although all the five music styles were rated with no difference in familiarity in the current study, pop music may be more acceptable and comprehensible than other styles. Practically, the findings here provided the neural basis of pop music's multiple functions in emotion regulation and brain neural plasticity.

Limitations

No correlations were found between emotional ratings and fMRI activation. Music listening involves a dynamic change in the neural mechanisms. One's peak brain activation can easily get lost in the scanning of several seconds. Therefore, the fMRI activation of the low temporal resolution here was hard to match with listeners' subjective emotional rating. The other limitation was no analysis conducted in the interaction effects of the music style, musical attributes, and demographic characteristics. The music style is a mirror of one's psychological needs and tightly connected with ages, sex, culture, and personality (Schäfer & Sedlmeier, 2010). In the following study, more neural evidence of high temporal resolution and more demographic details are needed to explain the emotional effects of different music styles.

Conclusion

Music style is a multiple-level acoustic feature and a vital label in human daily music using. It is of significant value to explore its connection with listeners' emotional experience. Overall, our current study found that different styles of music can evoke different emotions and induce differentiated brain activities. Classical music can enhance listeners' positive emotion and decrease emotion arousal, which can be used in emotion regulation and inhibition of impulsive behavior. Rock music is significant in enhancing listeners' emotional arousal and may be more susceptible to the conditions of music appreciation. Pop music, with moderate emotional arousal, activated the strongest brain area in fMRI, which may be effective in further regulating emotion and exploring human music activity. These neural findings provided an effective neural evidence of different music styles during emotion-evoking.

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References

Angulo-Perkins, A., Aubé, W., Peretz, I., Barrios, F. A., Armony, J. L., & Concha, L. (2014). Music listening engages specific cortical regions within the temporal lobes: Differences between musicians and non-musicians. *Cortex*, *59*, 126–137. doi:10.1016/j.cortex.2014.07.013

Baker, D. (2005). Rock rebels and delinquents: The emergence of the rock rebel in 1950s "youth problem" films. *Continuum*, *19*, 39–54. doi:10.1080/1030431052000336289

Bangert, M., & Altenmüller, E. O. (2003). Mapping perception to action in piano practice: A longitudinal DC-EEG study. *BMC Neuroscience*, *4*, 26. doi:10.1186/1471-2202-4-26

Baumann, S., Koeneke, S., Meyer, M., Lutz, K., & Jäncke, L. (2005). A network for sensory-motor integration: What happens in the auditory cortex during piano playing without acoustic feedback? *Annals of the New York Academy of Sciences*, *1060*, 186–188. doi:10.1196/annals.1360.038

Baumgartner, T., Lutz, K., Schmidt, C. F., & Jäncke, L. (2006). The emotional power of music: How music enhances the feeling of affective pictures. *Brain Research*, *1075*, 151–164. doi:10.1016/j.brainres.2005.12.065

Baumgartner, T., Willi, M., & Jäncke, L. (2007). Modulation of corticospinal activity by strong emotions evoked by pictures and classical music: A transcranial magnetic stimulation study. *NeuroReport*, *18*, 261–265. doi:10.1097/WNR.0b013e328012272e

Belden, A., Zeng, T., Przysinda, E., Anteraper, S. A., Whitfield-Gabrieli, S., & Loui, P. (2020). Improvising at rest: Differentiating jazz and classical music training with resting state functional connectivity. *NeuroImage*, *207*, 116384. doi:10.1016/j.neuroimage.2019.116384

Bennett, A. (2001). *Popular music and youth culture: Music, identity, and place*. New York, NY: Macmillan. doi:10.2307/3089767

Bhatti, A. M., Majid, M., Anwar, S. M., & Khan, B. (2016). Human emotion recognition and analysis in response to audio music using brain signals. *Computers in Human Behavior*, *65*, 267–275. doi:10.1016/j.chb.2016.08.029

Bogert, B., Numminen-Kontti, T., Gold, B., Sams, M., Numminen, J., Burunat, I., . . . Brattico, E. (2016). Hidden sources of joy, fear, and sadness: Explicit versus implicit neural processing of musical emotions. *Neuropsychologia*, *89*, 393–402. doi:10.1016/j.neuropsychologia.2016.07.005

Brattico, E., Alluri, V., Bogert, B., Jacobsen, T., Vartiainen, N., Nieminen, S. K., & Tervaniemi, M. (2011). A functional MRI study of happy and sad emotions in music with and without lyrics. *Frontiers in Psychology*, *2*, 308. doi:10.3389/fpsyg.2011.00308

Burkhard, A., Elmer, S., & Jäncke, L. (2019). Early tone categorization in absolute pitch musicians is subserved by the right-sided perisylvian brain. *Scientific Reports*, *9*, 1419. doi:10.1038/s41598-018-38273-0

Capers, B. (2009). Crime music. *Ohio State Journal of Crime Law*, *7*, 749–768.

Chan, S. W., Sussmann, J. E., Romaniuk, L., Stewart, T., Lawrie, S. M., Hall, J., . . . Whalley, H. C. (2016). Deactivation in anterior cingulate cortex during facial processing in young individuals with high familial risk and early development of depression: fMRI findings from the Scottish Bipolar Family Study. *Journal of Child Psychology and Psychiatry*, *57*, 1277–1286. doi:10.1111/jcpp.12591

Cook, T., Roy, A. R., & Welker, K. M. (2019). Music as an emotion regulation strategy: An examination of genres of music and their roles in emotion regulation. *Psychology of Music*, *47*, 144–154. doi:10.1177/0305735617734627

Coyne, S. M., & Padilla-Walker, L. M. (2015). Sex, violence, & rock n'roll: Longitudinal effects of music on aggression, sex, and prosocial behavior during adolescence. *Journal of Adolescence*, *41*, 96–104. doi:10.1016/j.adolescence.2015.03.002

Eerola, T. (2011). Are the emotions expressed in music genre-specific? An audio-based evaluation of datasets spanning classical, film, pop and mixed genres. *Journal of New Music Research*, *40*, 346–366. doi:10.1080/09298215.2011.602195

Fried, R. (1990). Integrating music in breathing training and relaxation: II. Applications. *Biofeedback and Self-Regulation*, *15*, 171–177. doi:10.1007/BF00999146

Gerdner, L. A. (2000). Effects of individualized versus classical "relaxation" music on the frequency of agitation in elderly persons with Alzheimer's disease and related disorders. *International Psychogeriatrics*, *12*, 49–65. doi:10.1017/S1041610200006190

Grahn, J. A., & Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. *Journal of Cognitive Neuroscience*, *19*, 893–906. doi:10.1162/jocn.2007.19.5.893

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Review Neuroscience*, *8*, 393–402. doi:10.1038/nrn2113

Hoyt, D. B. (2004). Rock on—Staying focused on our way to greatness. *Journal of Trauma and Acute Care Surgery*, *56*, 1–6. doi:10.1097/01.TA.0000100172.39403

Istók, E. (2013). *Cognitive and neural determinants of music appreciation and aesthetics*. Helsinki, Finland: University of Helsinki.

Johnson, J. (2002). *Who needs classical music? Cultural choice and musical value*. Oxford, UK: Oxford University Press.

Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Review Neuroscience*, *15*, 170–180. doi:10.1038/nrn3666

Koelsch, S., Rohrmeier, M., Torrecuso, R., & Jentschke, S. (2013). Processing of hierarchical syntactic structure in music. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 15443–15448. doi:10.1073/pnas.1300272110

Kontukoski, M., Paakki, M., Thureson, J., Uimonen, H., & Hopia, A. (2016). Imagined salad and steak restaurants: Consumers' colour, music and emotion associations with different dishes. *International Journal of Gastronomy and Food Science*, *4*, 1–11. doi:10.1016/j.ijgfs.2016.04.001

Krumhansl, C. L. (2017). Listening niches across a century of popular music. *Frontiers in Psychology*, *8*, 431. doi:10.3389/fpsyg.2017.00431

Kumaran, D. S. (2018, June). *Using EEG-validated music emotion recognition techniques to classify multi-genre popular music for therapeutic purposes*. Paper presented at the Conferences of International Student Science Fair. Retrieved from https://digitalcommons.imsa.edu/issf2018/presentations/all/4/

Lambe, A. (2017). *Where words fail: A quantitative analysis of the influence of musical genre, emotion & personality* (Doctoral dissertation). Dublin Business School, Dublin, UK.

Lartillot, O., Toiviainen, P., & Eerola, T. (2008). A matlab toolbox for music information retrieval. In: C. Preisach, H. Burkhardt, L. Schmidt-Thieme, & R. Decker (Eds.), *Data analysis, machine learning and applications* (pp. 261–268). Berlin, Germany: Springer. doi:10.1007/978-3-540-78246-9_31

Li, W., & Qian, M. (1995). Revision of the norm of Chinese college students on the State-Trait Anxiety Scale. *J PKU* (Natural Science Edition), *31*, 108–114.

Liu, Y., Liu, G., Wei, D., Li, Q., Yuan, G., & Wu, S. (2018). How does musical tempo affect musicians and non-musicians' emotional experience during music listening? *Frontiers in Psychology*, *9*, 2118. doi:10.3389/fpsyg.2018.02118

Loui, P., Zamm, A., & Schlaug, G. (2012). Absolute pitch and synesthesia: Two sides of the same coin? Shared and distinct neural substrates of music listening. In E. Cambouropoulol, C. Tsougras, P. Mavromatis, & C. Pastiadis (Eds.), *International conference on music perception and cognition* (pp. 618–623). Thessaloniki, Greece: Aristotle University of Thessaloniki.

Lu, D. J., Dai, L., Wu, H., & Qin, J. (2012). EEG study on the soothing effect of different types of music on sadness. *Psychology Exploring*, *3*, 369–375.

Nanni, L., Costa, Y. M., Lumini, A., Kim, M. Y., & Baek, S. R. (2016). Combining visual and acoustic features for music genre classification. *Expert Systems With Applications*, *45*, 108–117. doi:10.1109/ICMLA.2011.48

Park, M., Gutyrchik, E., Bao, Y., Zaytseva, Y., Carl, P., Welker, L., . . . Meindl, T. (2014). Differences between musicians and non-musicians in neuro-affective processing of sadness and fear expressed in music. *Neuroscience Letters*, *566*, 120–124. doi:10.1016/j.neulet.2014.02.041

Paul, L. K., Lautzenhiser, A., Brown, W. S., Hart, A., Neumann, D., Spezio, M., & Adolphs, R. (2006). Emotional arousal in agenesis of the corpus callosum. *International Journal of Psychophysiology*, *61*, 47–56. doi:10.1016/j.ijpsycho.2005.10.017

Rea, C., MacDonald, P., & Carnes, G. (2012). Listening to classical, pop, and metal music: An investigation of mood. *Emporia State Research Studies*, *46*, 1–3. doi:10.1017/S0261143013000482

Rentfrow, P. J., & Gosling, S. D. (2003). The do re mi's of everyday life: The structure and personality correlates of music preferences. *Journal of Personality and Social Psychology*, *84*, 123–1256. doi:10.1037/0022-3514.84.6.1236

Satpute, A. B., & Lindquist, K. A. (2019). The default mode network's role in discrete emotion. *Trends in Cognitive. Science*, *23*, 851–864. doi:10.1016/j.tics.2019.07.003

Schaefer, R. S., Morcom, A. M., Roberts, N., & Overy, K. (2014). Moving to music: Effects of heard and imagined musical cues on movement-related brain activity. *Frontiers in Human Neuroscience*, *8*, 774. doi:10.3389/fnhum.2014.00774

Schäfer, T., & Sedlmeier, P. (2010). What makes us like music? Determinants of music preference. *Psychology of Aesthetics, Creativity and Arts*, *4*, 223–234. doi:10.1037/a0018374

Schellenberg, E. G., & von Scheve, C. (2012). Emotional cues in American popular music: Five decades of the Top 40. *Psychology of Aesthetics, Creativity and Arts*, *6*, 196–203. doi:10.1037/a0028024

Scheufele, P. M. (2000). Effects of progressive relaxation and classical music on measurements of attention, relaxation, and stress responses. *Journal of Behavioral Medicine*, *23*, 207–228. doi:10.1023/A:1005542121935

Shobe, E. R. (2014). Independent and collaborative contributions of the cerebral hemispheres to emotional processing. *Frontiers in Human Neuroscience*, *8*, 230. doi:10.3389/fnhum.2014.00230

Steinbeis, N., & Koelsch, S. (2008). Comparing the processing of music and language meaning using EEG and fMRI provides evidence for similar and distinct neural representations. *PLoS ONE*, *3*(5), Article e2226. doi:10.1371/journal.pone.0002226

Straw, W. (1984). Characterizing rock music cultures: The case of heavy metal. *Canadian University Music Review*, *5*, 104–122.

Sun, Y., Zhang, C., Duan, S., Du, X., & Calhoun, V. D. (2019). Neural intrinsic functional connectivity associated with sensation seeking in heavy metal music and classical music lovers. *NeuroReport*, *30*, 317–322. doi:10.1016/j.bbr.2011.10.026

Susino, M., & Schubert, E. (2019). Cultural stereotyping of emotional responses to music genre. *Psychology of Music*, *47*, 342–357. doi:10.1177/0305735618755886

Tachibana, A., Noah, J. A., Ono, Y., Taguchi, D., & Ueda, S. (2019). Prefrontal activation related to spontaneous creativity with rock music improvisation: A functional near-infrared spectroscopy study. *Scientific Reports*, *9*, 16044. doi:10.1038/s41598-019-52348-6

Treder, M. S., Purwins, H., Miklody, D., Sturm, I., & Blankertz, B. (2014). Decoding auditory attention to instruments in polyphonic music using single-trial EEG classification. *Journal of Neural Engineering*, *11*, 026009. doi:10.1088/1741-2560/11/2/026009

Vuilleumier, P., & Trost, W. (2015). Music and emotions: From enchantment to entrainment. *Annals of the New York Academy of Sciences*, *1337*, 212–222. doi:10.1111/nyas.12676

Weber, W. (2005). Who needs classical music? Cultural choice and musical value. *British Journal of Aesthetics*, *11*, 499–500. doi:10.1215/0961754X-11-3-499-a

Wilson, C. V., & Aiken, L. S. (1977). The effect of intensity levels upon physiological and subjective affective response to rock music. *Journal of Music Therapy*, *14*, 60–76. doi:10.1093/jmt/14.2.60

Yudkin, J. (2007). *Understanding music* (Reprint). London, England: Pearson.

Zatorre, R. J., Chen, J. L., & Penhune, V. B. (2007). When the brain plays music: Auditory-motor interactions in music perception and production. *Nature Review Neuroscience*, *8*, 547–558. doi:10.1038/nrn2152

Zatorre, R. J., Perry, D. W., Beckett, C. A., Westbury, C. F., & Evans, A. C. (1998). Functional anatomy of musical processing in listeners with absolute pitch and relative pitch. *Proceedings of the National Academy of Sciences of the United States of America*, *95*, 3172–3177. doi:10.1073/pnas.95.6.3172

Zentner, M., Grandjean, D., & Scherer, K. R. (2008). Emotions evoked by the sound of music: Characterization, classification, and measurement. *Emotion*, *8*, 494–521. doi:10.1037/1528-3542.8.4.494