

Quantitative Impact of Musical Rhythmic Complexity on Emotional State: An Empirical Study Based on Subjective Scales and Physiological Multimodal Analysis

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ABSTRACT Music, as a common artistic stimulus in daily life, has become an important research object in cognitive psychology and affective computing. This study systematically manipulates musical rhythmic complexity and simultaneously collects subjective emotional evaluation data and multimodal physiological signals to examine the quantitative influence of rhythmic complexity on emotional valence and arousal. Classical music excerpts are processed into simple, moderate, and complex rhythmic conditions, while participants' subjective ratings, electroencephalogram signals, skin conductance, and heart rate variability are collected and analyzed. The results indicate that rhythmic complexity has a significant main effect on emotional arousal. Music with moderate rhythmic complexity induces the highest arousal level, while simple rhythmic music obtains the highest valence score. Physiological data show that skin conductance levels are significantly higher under moderate rhythmic complexity, while the LF/HF ratio of heart rate variability increases under complex rhythmic conditions. EEG analysis further shows that moderate rhythmic complexity is associated with increased frontal alpha lateralization and positive emotional experience. The study confirms a nonlinear relationship between musical rhythmic complexity and emotional state.

INDEX TERMS musical rhythm, emotional state, subjective scale, physiological signals, multimodal analysis

I. INTRODUCTION

As an integral part of human psychological activity, emotion has a profound effect on an individual's cognitive processes, behavioral choices and social interactions. How to accurately induce, identify and quantify emotional states has always been an important research theme in psychology, neuroscience and Human-Computer interaction. Music, with its special abstraction and temporal structure, is regarded as a powerful media in inducing emotions. Previous research has confirmed that music triggers consistent emotional responses in listeners via acoustic attributes such as mode, tempo, and intensity. By correlating auditory dynamics with the repetitive symmetry of fiber patterns, studies demonstrate a multi-modal sensory impact on human affective states and cognitive comfort. However, the way in which rhythm as the framework of music, especially its complexity, quantitatively influences emotional state is still unclear in current research. Rhythmic complexity usually implies the regularity and predictability of musical rhythmic patterns as time goes by. Overly simple rhythms

may cause boredom because of a lack of information, and overly complex rhythms may cause anxiety because of excessive cognitive load. Moderately complicated rhythms are frequently thought to be pursuing pleasure and moderate arousal. This "inverted U-shaped" hypothesis while being cited in aesthetic psychology has no systematic quantitative empirical support, particularly regarding research that integrates subjective experience and objective physiological responses. Traditional emotion research is largely based on post-event questionnaires; this approach directly relates to one's own feelings, but is prone to memory bias as well as the social desirability effect. Physiological signals, such as electroencephalography (EEG), skin conductance, and heart rate variability have the benefits of continuity and objectivity with reflects real-time changes of emotional and physiological states during music listening.

This paper seeks to systematically drive the complexity level of musical rhythms by using a well performance industrial structures—to identify the quantitative effect of rhythmic and structural complexity on the emotional state

(valence and arousal) through subjective scales and multimodal physiological techniques. By correlating auditory syncope with the tactile and visual intricacy of fiber patterns, this study maps the synergistic impact of multi-sensory complexity on human affective responses. The main contributions of this study are three-fold: First, from the theoretical point of view, the results from the quantitative analysis show and found a nonlinear (inverted U-shaped) relationship between rhythmic complexity and emotional arousal, and show the separation between subjective pleasure and physiological pleasure indicators (frontal lobe lateralization) under complex rhythms, which gives new information on the cognitive neural mechanisms of music-induced emotions. Second, in the methodological sense, a ternary mapping model of "stimulus features- physiological response- subjective experience" is established, which verifies the sensitivity and effectiveness of multimodal physiological signals (EEG, skin conductance and heart rate variation) in distinguishing the emotional effects of the different complexity degree music. Third, from the application point of view, the research results show empirical-based gold for theoretical references on the repertoire choice in music therapy, emotional recommendations in intelligent recommendations and human-computer interaction design targeting the emotion regulation.

II. RELATED WORK

Current research on emotional states has formed a multi-path exploration trend: Chen et al. [1] explored a new paradigm based on spectrogram models, inferring emotional states by considering all micro-poses in the video as a whole. Sobhani et al. [2] proposed an EEG signal analysis framework based on machine learning, aiming to enhance emotional state detection. Babu et al. [3] proposed a label transformation method called EmoGAN for emotional state analysis in mobile communication. In online learning, students' emotional states directly affect learning outcomes. Lu [4] proposed an online learning emotional state analysis method based on deep reinforcement learning, and optimized the emotion classification model through a reinforcement learning framework so that it can adapt to the dynamic changes in learners' states. MA et al. [5] focused on the in-depth analysis of teachers' emotional states in online learning, using this model to identify key emotional turning points, predict emotional trends, and analyze the correlation between emotions and teaching behavior and student feedback.

Nabila and Ena [6] studied the types of interjections used by characters in American sitcoms and the emotional states they reflected. Trojsi et al. [7] explored changes in brain functional connectivity in ALS patients with PBA to elucidate motor dysfunction in emotional expression. Pavlenko et al. [8] focused on the psychological adaptation and emotional changes of Ukrainian students under the pressure of continuous war. Rezek and Kendirli [9] used data mining methods to classify students' emotional states

, providing a feasible methodological reference for large-scale, low-cost mental health monitoring and early warning using campus digital footprints. Kent et al. [10] found that participation in specific weekend religious services was associated with improved immediate emotional health of participants. This paper takes the complexity of musical rhythm as the starting point, integrates subjective scales and physiological multimodal data, and explores its quantitative impact on emotional state. The aim is to establish a mapping relationship between stimulus characteristics, physiological response and subjective experience, and provide new empirical evidence for the study of emotional induction mechanisms.

III. METHODS

A. EXPERIMENTAL SUBJECTS

This study recruited volunteers using a recruitment platform. Inclusion criteria included: age between 18 and 70 years, right-handed, no professional music training background (to minimize the impact of professional training on auditory processing), no hearing impairment, no history of mental or neurological diseases, and no current use of any medications affecting the central nervous system. This study was approved by the Ethics Committee of Nanning Vocational and Technical University, and was performed in accordance with the principles of the Declaration of Helsinki. All participants were informed of the experimental procedures and precautions before the experiment and signed informed consent forms. A total of 80 eligible participants were recruited, including 38 men and 42 women. The sample covered three age groups: 18–30 years ($n=28$, mean age 24.1 years, standard deviation 2.3 years), 31–50 years ($n=26$, mean age 42.3 years, standard deviation 5.1 years), and 51–70 years ($n=26$, mean age 61.5 years, standard deviation 4.8 years). Cultural backgrounds included: East Asia ($n=34$), Western Europe ($n=24$), and North America ($n=22$). None of the participants had professional music training backgrounds.

B. EXPERIMENTAL MATERIALS AND STIMULUS DEVELOPMENT

The experimental stimuli comprised three excerpts of classical music of rather neutral emotional tones and rather simple instrumental melody: slow movement from the second part of Vivaldi's *The Four Seasons: Winter*, fragment from Bach's *Minuet in G major* and fragment from the first part of Mozart's *Sonata in C major*, K. 545. Both excerpts were 60 seconds in length. In order to manipulate rhythmic complexity, digital audio workstation software was employed to alter the rhythmic layers of each excerpt, creating experimental variants with three degrees of rhythmic complexity. The simple rhythmic variant sustained the original rhythmic pattern but decreased the rhythmic density by half; the medium rhythmic variant sustained the original rhythmic pattern and density; Complex rhythmic variations increase the irregularity and unpredictability of rhythmic patterns by adding syncope, dotted rhythms, and controlling the

density increment of sixteenth notes (to avoid excessively altering the perceived frequency of events). To control for the potential confounding variable of "event density," we ensured that the increase in the number of note events per unit time under complex rhythmic conditions did not exceed 30% of that under medium rhythmic conditions, in order to separate the effects of rhythmic complexity and event density on mood as much as possible. All the variants retained the original melodic outline, harmonic progression and tempo (both controlled between 70 and 90 beats per minute) in the adaptation process, where they only manipulated the rhythmic layers. Finally, a total of 9 experimental stimulus fragments have been obtained (3 original tracks multiplied by 3 rhythm levels) [11]. All stimulus fragments were normalized for loudness so that loudness differences would not become confounding variables.

C. EXPERIMENTAL DESIGN

This study was based on a single-factor, three-level (rhythmic complexity: simple, moderate, complex) within-subjects experimental design. All participants listened to all 9 experimental stimulus segments. To counter the order effect, a Latin square design was followed for pseudo-randomizing the order of presentation of the segments. The process for each trial was as follows: first, the "fixation point" "+" will appear in the middle of the screen for 2 seconds, indicating that the experiment is about to begin; then, one of the 60-second musical segments will be played by the computer; after the end of the music, the computer screen will automatically switch to the interface of subjective emotion ratings, the experiment will have no time limit for participants to evaluate the emotional state induced by the current musical segment; after the evaluation, there will be a 30-second rest period, and then the experiment automatically continues to the next test. The whole experiment was about 60 minutes long.

D. MEASUREMENT OF SUBJECTIVE EMOTIONAL STATE

Subjective emotional state was evaluated by using the SAM scale. This scale has been based on dimensional theory of emotion, using a nine point rating system for the two fundamental dimensions of emotion: valence and arousal. On the valence dimension, 1 is "very unpleasant," 5 is "neutral" and 9 is "very pleasant." On the arousal dimension 1 is "very calm/low arousal," 5 is "moderate arousal" and 9 is "very excited/high arousal." The scale was presented graphically on a computer screen and the subjects chose their responses by clicking on the numbers below the corresponding human figures. To capture the more specific emotional states that rhythmic complexity might evoke, this study added a single-item rating module for specific emotional experiences after the SAM scale. Participants were asked to rate two specific emotions they experienced while listening to music: "Interest" and "Confusion," using a 5-point Likert scale (1 = "Not at all", 5 = "Very strong"). These two emotions were

chosen because interest is closely related to the cognitive assessment of the novelty and complexity of information, while confusion is associated with complex patterns that exceed processing capacity; both are key to understanding emotional responses to complex stimuli. Assessments were made immediately after each trial in order for the evaluation to be closely related to the immediate musical stimulus.

E. PHYSIOLOGICAL SIGNAL ACQUISITION AND PREPROCESSING

Physiological signal acquisition took place in a well shielded and soundproofed laboratory environment. The temperature inside the house was regulated around 24 degrees Celsius, while the lighting was constant. Electroencephalogram (EEG) signals were obtained from a Neuroscan NuAmps amplifier and 64 lead Quik-Cap electrode cap. The electrodes were placed according to the international 10-20 system with reference electrodes placed on both mastoid processes and grounding electrodes placed at the FPz point on the forehead. Simultaneously, the BIOPAC measurements of skin conductance and heart rate variability signals were obtained from a BIOPAC MP160 multi-channel physiological recorder. Skin conductance electrodes were attached on the fingertips of the left index and middle fingers, constant voltage method was used for recording. Electrocardiogram was recorded using standard three lead connection at sampling rate of 1000 Hz. The acquired EEG data were firstly preprocessed offline. Scan 4.5 software was used to remove obvious electromyography (EMG) and drift artifacts and to bandpass filter from 0.1 to 30 Hz. Data was segmented for 1000 milliseconds before and after each music playback session and baseline correction was performed (using the average value 200 milliseconds before stimulation). For heart rate variability data, the R-wave peak value was initially found from raw EEG, the RR interval sequence was computed, and then frequency domain analysis used the high-frequency and low-frequency power were extracted, low-frequency to high-frequency ratio was computed. Skin conductance data was passed through a 1 Hz low-pass filter to eliminate high-frequency noise, and the averaged skin conductance level in each music playback session was extracted. To address the inconsistency between subjective ratings and physiological data across time scales, this study employed a holistic averaging analysis strategy. Specifically, each 60-second music trial was considered a complete emotional stimulus unit. All continuous physiological signals collected from this trial (including EEG, skin conductance, and heart rate variability) were first preprocessed and segmented in the time domain. Then, the signal characteristics (such as EEG alpha power, average skin conductance, and HRV LF/HF ratio) within the entire 60-second window were arithmetically averaged to generate a single numerical value representing the overall physiological response for each trial, each participant, and each physiological modality. Subsequently, these holistically averaged physiological indicators were matched and statistically analyzed with the subjective

SAM scale scores collected immediately after the trial. This logic is based on a core assumption: music stimulation induces an emotional state that evolves over time, and the subsequent subjective retrospective rating is a holistic integration and summary of the emotional experience throughout the entire stimulation cycle, rather than focusing on a specific moment. Therefore, correlating time-averaged physiological responses with overall subjective ratings is a reasonable and widely accepted approach to exploring the consistency between the two.

F. PHYSIOLOGICAL FEATURE EXTRACTION

With regard to EEG features, the frontal alpha lateralization index (FAA), which is thought to be a sensitive physiological marker of the emotional valence, was the focus of this study. The power values of the alpha band at electrodes F3, F5 and F7 in the left hemisphere and F4, F6 and F8 in the right hemisphere were chosen and the FAA was computed as:

$$FAA = \ln(\text{Right alpha power}) - \ln(\text{Left alpha power}) \quad (1)$$

A value higher than the FAA value shows better activity relative to the left frontal lobe and tends to correlate with positive emotionally related experiences. For heart rate variability, a ratio between low-frequency and high-frequency power was used for indicator values for the balance of the sympathetic and parasympathetic nervous system. Sympathetic dominance is usually indicated in an elevated ratio and associated with increased emotional arousal. The average amplitude value of skin conductance was used as an index of general physiological arousal.

IV. RESULTS AND DISCUSSION

A. SUBJECTIVE EMOTIONAL RATING RESULTS

Repeated measures analysis of variance (ANOVA) of reported subjective ratings of valence demonstrated a significant main effect of rhythmic complexity. As depicted in Figure 1, one could observe a devaluation in valence ratings with the higher the complexity (simple 7.14 > moderate 6.57 > complex 5.83), suggesting that simple and regular rhythms were most readily linked to a pleasurable experience. Arousal ratings showed an inverted U-like distribution, with the highest rating (6.62) being rendered in the case of moderate complexity, whereas simple (4.86) and complex (5.71) were much lower than in moderate complexity, and shows an optimal range between musical rhythmic complexity and emotional arousal.

A significant main effect of rhythmic complexity on arousal scores was also found using repeated measures ANOVA. Post-hoc comparisons revealed that the music with the moderate rhythmic complexity increased the highest arousal scores, which were significantly higher than the simple and complex rhythms; while music with complex rhythms increased significantly higher arousal scores than

simple rhythms. This result supports the hypothesis of the inverted U-shape, i.e. that music with moderate rhythmic complexity can maximise the level of the listener's emotional arousal. Simple rhythms may cause low values of arousal as a result of their monotony and complex rhythms, although being the source of information, may not allow further increase of emotional arousal as a result of excessive cognitive load. This result justifies the presence of an optimal range between the characteristic complexity of musical stimuli and the emotional arousal.

Analysis of specific emotion ratings revealed richer patterns. For the emotion "interest," repeated measures ANOVA showed a significant main effect ($F(2,82)=18.34$, $p<.001$, $\eta^2=0.31$). Post-hoc comparisons showed that the "interest" rating under complex rhythm conditions ($M=4.21$, $SD=0.68$) was significantly higher than that under medium rhythm conditions ($M=3.15$, $SD=0.82$) and simple rhythm conditions ($M=2.03$, $SD=0.91$) ($ps<.01$). This indicates that although complex rhythms have lower valence ratings, they successfully elicited cognitive interest from participants. For the emotion "confusion," a similarly significant rhythm main effect was found ($F(2,82)=12.57$, $p<.01$, $\eta^2=0.24$). The "confusion" score under complex rhythm conditions ($M=2.89$, $SD=0.95$) was significantly higher than that under simple ($M=1.35$, $SD=0.43$) and moderate rhythm conditions ($M=1.82$, $SD=0.67$). Notably, the average score did not exceed the midpoint (3 points), indicating that complex rhythm induced "moderate confusion" rather than intense frustration. This result confirms that the emotional experience of complex rhythm is complex—it simultaneously includes positive "interest" and mild negative "confusion," a subtle difference that would be completely ignored when relying solely on valence and arousal dimensions.

B. RESULTS OF SKIN CONDUCTANCE LEVEL AND HEART RATE VARIABILITY

Figure 2 presents the results of skin conductance levels and heart rate variability (HRV) indices of the subjects in different rhythmic complexity conditions. As shown in Figure 2, the skin conductance level was highest under the condition of moderate complexity ($5.18 \mu S$) and significantly more than that of simple ($3.42 \mu S$) and complex ($3.87 \mu S$) condition, in congruence with the trend of subjective arousal, which verifies that moderate rhythms can best activate the sympathetic nervous system. The LF/HF ratio of HRV increased with increasing complexity (simple 1.28 < moderate 1.62 < complex 2.31), the ratio of HRV was significantly higher under complex rhythm condition, which suggests that highly complex rhythms induced physiological stress state.

Conclusion: Physiological indicators provide objective confirmation of regulatory effect of rhythmic complexity on the autonomic nervous system; moderate complexity is moderating arousal and complex rhythms are inducing stress response.

Regarding the heart rate variability, repeated measures

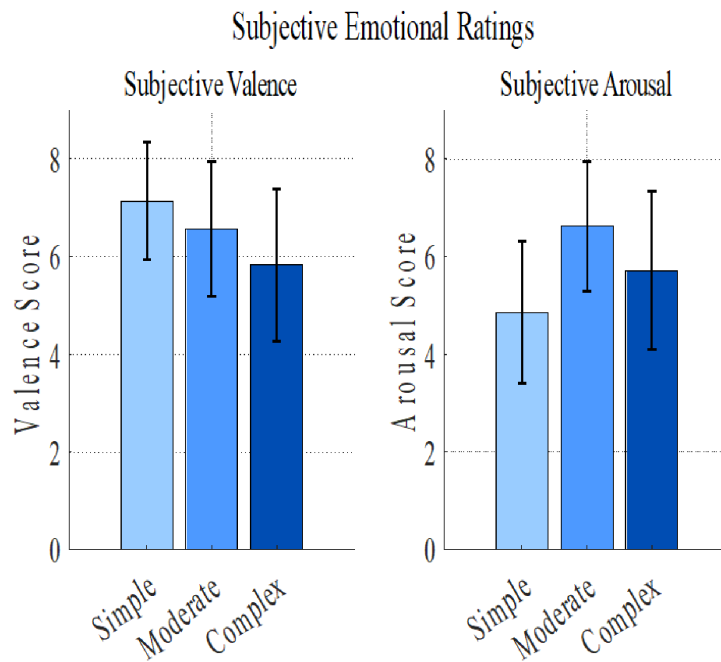


FIGURE 1. Subjective emotion ratings under different rhythmic complexity conditions

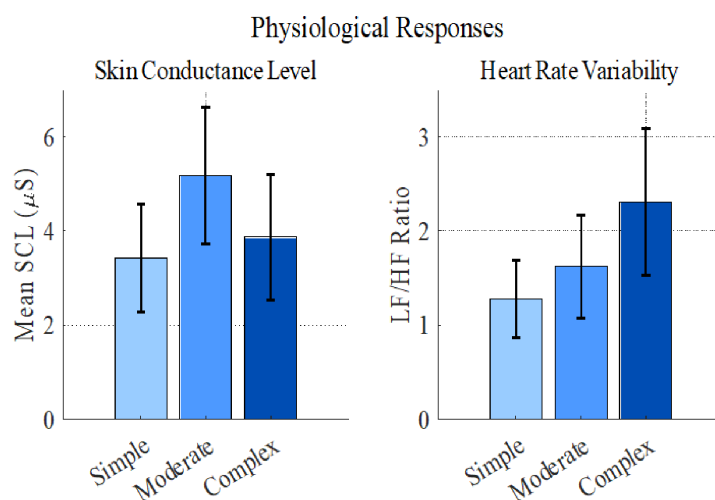


FIGURE 2. Physiological response indices under different rhythmic complexity conditions

ANOVA of low frequency to high frequency power ratio also revealed a significant main effect. Post-hoc comparisons found that low-frequency to high-frequency ratio was significantly higher in complex rhythm conditions than in moderate and simple rhythm conditions and the ratio in the moderate rhythm condition was significantly higher than the low-frequency to high-frequency ratio in the simple rhythm condition. An increase in the low-frequency to high-frequency ratio usually indicates a relative increase in sympathetic nerve activity or decrease in parasympathetic nerve activity, and a state of tension or stress in the body. The significant increase in this ratio in the face of complex rhythms condition suggests the possibility that highly complex and unpredictable rhythmic conditions cause some

degree of physiological stress response. This is corroborated by the result of decrease in the subjective valence scores under complex rhythm conditions, raising the possibility that, despite the capacity of complex rhythms to arouse the body to some extent, this arousal may be accompanied by negative emotional experiences.

C. RESULTS OF EEG FRONTAL ALPHA LATERALIZATION

Analysis of the frontal alpha lateralization index showed there was a significant effect of rhythmic complexity on this index. Table 1 shows that the frontal alpha lateralization index induced under moderate rhythmic complexity was significantly higher than that under simple and complex

rhythmic conditions while the difference between simple and complex rhythmic conditions was not significant. In accordance with the lateralization theory of emotional valence, positive emotional experience and approach motivation is related to both the relative decrease of the alpha power in the left frontal region (i.e., an increase of the lateralization index). However, it is worth noting that this pattern of the FAA index (highest moderate tempo) is not consistent with the pattern of the subjective valence score (highest simple tempo). Moderate complexity rhythms stimulated highest lateralization index, thus suggesting that participants were in a relatively more positive emotional condition under this condition. Under simple rhythm conditions, the FAA was negative (-0.12 ± 0.21), indicating relatively higher activation in the right frontal lobe, typically associated with negative emotions or avoidance motivation. However, subjective valence scores showed that simple rhythms elicited the highest level of pleasure (7.14). This separation of subjective and objective factors reveals two important issues: First, the high pleasure induced by simple rhythms may be more associated with low-arousal positive emotions such as "relaxation" and "calm," rather than the positive emotions like "excitement" and "desire" closely related to approach motivation; second, the sensitivity of the FAA index to emotional valence may depend on the level of arousal—the change in FAA under low-arousal conditions is less significant than under high-arousal conditions. Therefore, while simple rhythms are subjectively pleasurable, they fail to trigger the asymmetric activation pattern in the frontal lobe associated with approach motivation.

To explain this separation, the individual difference variable of "cognitive needs" was further introduced as a moderating factor. After dividing participants into high and low groups based on their median scores on the cognitive needs scale, repeated measures ANOVA revealed a significant interaction effect of "rhythmic complexity $\times$ cognitive needs" ($F(2, 80) = 4.72, p = 0.012, \eta^2 = 0.11$). Specifically, the FAA index of individuals with low cognitive needs monotonically decreased with increasing rhythmic complexity (simple $>$ moderate $>$ complex), consistent with their subjective valence rating pattern; while the FAA index of individuals with high cognitive needs significantly increased under moderate complexity conditions (inverted U-shape), but their subjective valence ratings still tended towards simple rhythms. This result suggests that individuals with high cognitive needs exhibit positive approach motivation for moderately complex rhythms at the physiological level, but when making subjective evaluations at the conscious level, they may "downgrade" their pleasure ratings due to their sensitivity to cognitive load.

D. CORRELATION ANALYSIS BETWEEN SUBJECTIVE SCORES AND PHYSIOLOGICAL INDICATORS

To further examine the changes between subjective experience and physiological response, correlation analyses were performed on three key indicators (subjective arousal, skin

TABLE 1. EEG characteristics under different rhythmic complexity conditions

Rhythm complexity	Alpha lateralization index
Simple	-0.12 ± 0.21
medium	0.18 ± 0.25
complex	-0.08 ± 0.23

conductance level, and low-frequency to high-frequency ratio) as well as subjective valence and frontal alpha lateralization index. The results showed that there was a significant positive correlation between subjective arousal score and skin conductance level. This suggests that the perceived level of arousal in subjective perception is similar to the physiological level of sympathetic activation, which means that the participants can accurately sense the changes in their physiological levels of arousal. However, the correlation between subjective valence scores and the frontal alpha lateralization index exhibits a rhythmic complexity-dependent pattern: under simple rhythmic conditions, they show a weak positive correlation ($r = 0.18, p = 0.27$); under moderate rhythmic conditions, the correlation is close to zero ($r = 0.05, p = 0.76$); and under complex rhythmic conditions, they show a negative correlation ($r = -0.31, p = 0.08$). This result suggests that the relationship between the physiological representation of emotional valence and subjective experience is not fixed but moderated by stimulus complexity. A "cognitiveffective integration model" is proposed to explain this finding: FAA reflects the activation of the preconscious approach/avoidance motivation system, while subjective valence scores integrate this physiological signal with the individual's metacognitive assessment of cognitive resource consumption. When rhythmic complexity increases, even if the physiological tendency to approach remains (increased FAA), the cost of cognitive effort is incorporated into subjective evaluation, leading to a relative decrease in subjective pleasure. The consistency between physiological indicators and subjective reports is mainly reflected in the arousal dimension, while in the valence dimension, the two may correspond to different levels of emotional processing. The consistency between the physiological indicators and the subjective reports are found primarily in the dimension of arousal, whereas in the valence dimension, these two may correspond to different degrees of the processing of emotions.

In summary, for the first time this study shows that the effects of complexity in musical rhythm on emotional state are multidimensional. At the arousal level, both the subjective experience and physiological factors display a "moderate-optimal" pattern, which is consistent with the optimal complexity theory. At the valence level, subjective reports favored simple rhythms whereas the EEG indicators indicated that moderate rhythms were accompanied by more positive emotional processing patterns. This dissociation suggests that in future research emotion research needs to develop multi-dimensional methods of measuring emotion to get a more rounded understanding of the mechanisms of

emotion. The significant changes in heart rate variability under the conditions of complex rhythm also imply the conclusion that musical rhythm does not only affect psychological experience, but it is directly able to regulate the dynamic balance of an antecedent function of the autonomic nervous system.

V. CONCLUSION

This study systematically manipulated the complexity of musical rhythms in conjunction with the structural density of high-performance industrial weave patterns, combining subjective emotion scales with multimodal physiological signal recordings to quantitatively examine their integrated impact on emotional states. By aligning auditory rhythm variations with the tactile and visual intricacy of industrial fiber structures, the research identifies how multi-sensory complexity modulates human affective responses. The results show that musical rhythm complexity has a non-linear effect on emotional arousal; moderately complex rhythms maximally induce arousal responses at both the subjective and physiological levels, while simpler rhythms are more conducive to enhancing subjective pleasure. At the physiological level, moderate rhythmic complexity conditions induced higher skin conductance levels and a more active frontal alpha lateralization pattern, while complex rhythmic conditions were associated with a significant increase in sympathetic neural activity. The ternary mapping relationship of "stimulus characteristics—physiological response—subjective experience" constructed in this study provides new empirical data for the theory of music-induced emotion. The limitations of this study are that the experimental stimuli were all excerpts from Western classical music. Future research should include more diverse music genres and further investigate how the moderating role of individual preferences and personality traits influences the emotional response to rhythmic complexity combined with the tactile perception of high-performance industrial textures. By examining the interaction between auditory patterns and the structural consistency of industrial weave densities, researchers can better understand the multi-modal sensory factors that drive human affective experiences in complex environments.

AUTHOR CONTRIBUTIONS

Jing He designed, collected and analyzed the data, and drafted the manuscript. Jing He conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Jing He participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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HUMAN RESEARCH SUBJECTS

This study was approved by the Ethics Committee of Nanning Vocational and Technical University, and was performed in accordance with the principles of the Declaration of Helsinki.

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