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A Study on the Auditory Characteristics of Clarinet Timbre and its Healing Effects

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Abstract: With the acceleration of social life rhythm, psychological anxiety and mental sub-health have become common contemporary problems. As a safe, non-invasive and easily accepted psychological intervention method, music therapy has been widely applied in mental adjustment. The clarinet features warm, mellow and balanced timbre with high auditory comfort, showing natural emotional soothing advantages. This study adopts literature analysis, logical induction and auditory experience summary, combining interdisciplinary achievements of instrumental acoustics, music psychology and neurorehabilitation medicine, to systematically explore the acoustic characteristics, aesthetic value and psychosomatic healing mechanism of clarinet timbre. The results show that positive auditory stimulation of clarinet timbre can effectively alleviate negative emotions, relieve psychological stress and regulate neural activity. Its stable acoustic vibration and gentle spectral distribution fit human relaxation rhythms and produce positive intervention effects from psychological, neurophysiological and aesthetic empathy dimensions. This study fills the research gap in single-instrument timbre therapy and provides scientific theoretical support and practical reference for public daily relaxation, mental health education and music rehabilitation intervention.

Keywords: Clarinet; Timbre Characteristics; Auditory Perception; Music Therapy; Emotion Regulation.

1. Introduction

1.1. Research Background

Since entering the new era, social competition has become increasingly fierce. The academic pressure on students, the work pressure on working professionals, and the life pressure on the general public have continuously overlapped, making psychological stress and emotional problems a nationwide and normalized social issue. Being in a high-pressure environment for a long time leads to continuous excitation of the sympathetic nervous system, easily resulting in problems such as emotional anxiety, mental tension, decreased sleep quality, reduced psychological resilience, and rampant negative emotions, seriously affecting individual physical and mental health and quality of life. Traditional psychological intervention methods often rely on counseling, medication, and exercise, which are costly, highly specialized, difficult to popularize, and have limited audience acceptance. Therefore, finding a safe, gentle, low-cost, easily accessible, and barrier-free method for normalized physical and mental regulation has become an important research direction in the field of mental health.

Music auditory intervention, with its unique advantages of being natural, comfortable, and universally applicable, has become one of the most valuable psychological intervention methods for widespread application. Numerous scientific studies have confirmed that beneficial music stimulation can regulate the activity of the cerebral cortex, optimize emotional perception, relieve mental fatigue, and improve psychological state, possessing stable physical and mental healing effects. Among many musical instrument timbres, the clarinet's timbre is soft, stable, pure, warm, and rich in layers, with extremely low auditory stimulation, highly compatible with the body's rhythms in a relaxed state, possessing natural therapeutic suitability.

Foreign scholar Yasui proved through auditory quantitative experiments that the clarinet ranks high in mellowness among woodwind instruments and is not prone to auditory fatigue when listened to for a long time [1]. However, looking at the current state of clarinet research in China, the academic community has long focused on performance techniques and stage performances, and rarely pays attention to the auditory value and psychological healing function of the clarinet's independent timbre. A large number of high-quality instrumental auditory resources have not been effectively developed and utilized. Although foreign countries have carried out scientific research on the acoustic mechanism and timbre perception of the clarinet, they have not yet formed a systematic research result on the physical and mental healing effect of the clarinet timbre. Therefore, carrying out special research on the auditory characteristics of clarinet timbre and its physical and mental healing effect has sufficient necessity and academic research value.

1.2. Research Significance

1.2.1. Theoretical Significance

This study breaks through the traditional clarinet research's single perspective that focuses on performance techniques, organically integrating instrument acoustics theory, timbre aesthetics theory, music psychology, neurorehabilitation medicine, and art therapy theory to construct a complete research logic system of "acoustic structure - timbre characteristics - auditory experience - physical and mental healing." By integrating domestic and international acoustic experiments, neurological evidence, and psychological scale research results, it systematically elucidates the underlying mechanism of clarinet timbre healing, enriches the cross-disciplinary research content of instrumental timbre and psychological perception, fills the gap in single-instrument timbre-specific healing research, and provides a scientific theoretical reference and research paradigm for subsequent similar instrumental healing research.

1.2.2. Practical Significance

This paper clearly shows the physical and mental healing benefits and uses of clarinet timbre, which can offer low-cost and daily emotional relief and stress reduction strategies to the general population, enabling people to independently control negative feelings and relieve psychological exhaustion. In the meantime, the results of the research can be transferred to other areas like mental health education in higher education institutions, art psychological counseling in primary and secondary schools, and art rehabilitation intervention, which is a practical and scalable route to campus-based psychological counseling and art therapy practice with high practical application value and social promotion importance.

1.3. Research Methods and Innovations

1.3.1. Research Methods

The paper primarily uses three research approaches to make the research content scientific, systematic and rigorous.

First and foremost, literature analysis. The systematic review of domestic and international research literature on the acoustics of clarinet, timbre perception, aesthetics of music, music therapy, and neurorehabilitation is performed, summarizing the results of existing research and its limitations, establishing the theoretical basis of research of this paper, and defining the entry point and framework of the research.

Second, theoretical research. The acoustic benefits, auditory features, and healing processes of clarinet timbre are thoroughly examined to develop a comprehensive theoretical research framework by integrating the appropriate theories of physical acoustics, music psychology, neuroscience, and art therapy.

Third, logical induction. This research classifies, summarizes and examines the results of available empirical studies, isolating the beneficial impacts of clarinet timbre on emotion control, nerve regeneration, and psychological calming, resulting in scientific and rigorous research findings.

1.3.2. Innovation Points

First, creative research outlook. Leaving the conventional paradigm of the clarinet playing technique study, the current research is centered on the auditory experience of the audience, emphasizing the therapeutic importance of the independent timbre of the clarinet, thereby overcoming the constraints of the traditional and rigid approaches to the study of the clarinet playing technique.

Second, innovative research dimensions. Integrating the dual scientific mechanisms of physical acoustics and neurophysiology, this study comprehensively elucidates the underlying logic of clarinet timbre therapy, from macroscopic psychological experience to microscopic nerve repair, resulting in a more three-dimensional and scientific research dimension.

Third, innovative research content. Addressing the current problem of generalized and overly generalized music therapy research, this study conducts refined therapeutic research on single instruments and single timbres, filling the research gap in the specialized field of instrumental timbre therapy.

2. Current Status of Domestic and International Research

2.1. Current Status of Domestic Research

Domestic research on clarinet art started relatively early. After years of development, it has formed a relatively mature and complete research pattern, but the overall research perspective has obvious limitations. Yao Yi clearly pointed out that the current domestic clarinet research generally suffers from an imbalance of "emphasizing technical training, neglecting aesthetic research, and neglecting audience experience". Most of the results focus on performance practice and teaching training, and very few studies are carried out from the auditory aesthetics, emotional value, and psychological perception of the timbre itself, ignoring the emotional soothing and physical and mental healing potential of the clarinet's independent timbre[2].

With the development of modern music theory and spectrum music research, domestic research has begun to gradually break through the limitations of traditional timbre cognition and pay attention to the multi-dimensional sound expression and stereo timbre characteristics of the clarinet. Xiang Yang took the Clarinet Concerto by modern composer Chen Yinshu as the research object, combined spectrum music thinking and multidimensional sound parameter theory, and deeply analyzed the sound expression characteristics of the clarinet in modern works. He proved that the clarinet can break through the traditional single and soft timbre paradigm, and form a multi-layered and three-dimensional sound effect through resonance superposition, spatial reflection and spectrum change, and has rich auditory expression potential[3]. This study broke the limitations of traditional clarinet timbre cognition and provided a new idea for the study of the multi-dimensional auditory value of clarinet timbre.

In the existing domestic research on clarinet application, Wang Jun pointed out that the clarinet occupies an irreplaceable important position in the woodwind section of the symphony orchestra with its warm and transparent, full-layered and unique timbre characteristics. Its timbre is highly inclusive and rich in artistic expression, and can be adapted to various musical styles and orchestral textures[4]. For a long time, the domestic academic community has generally regarded the clarinet timbre as an artistic carrier for stage performance and orchestral ensemble, focusing on how to optimize the timbre quality through breath, embouchure and fingering to serve the stage art presentation.

In the field of empirical research on music therapy, a large number of high-quality empirical results have emerged in China in recent years, which fully demonstrate the positive effect of music intervention on individual mental health, emotional regulation and physical and mental rehabilitation. Liao Zhiliu et al. used a mixed research method, combining quantitative scales and qualitative interviews, to conduct a music therapy course intervention experiment for medical graduate students. The results showed that long-term music auditory intervention can significantly improve the individual's positive emotional level, positive coping ability and psychological resilience, and effectively improve the psychological sub-health state of people under high pressure[5].

Chen Junrui et al. further conducted in-depth research from the microscopic neurophysiological level. By constructing a mouse depression model, they systematically explored the antidepressant mechanism of music combined with exercise intervention. The study confirmed that music stimulation can effectively inhibit neuroinflammation, reduce the level of systemic inflammation, repair the neuronal structure damaged by stress, and increase the number of Nissl bodies and

dendritic spine density in the hippocampus. From the physiological dimensions of nerve repair and inflammation regulation, they verified the physical and mental repair value of music[6].

According to the existing domestic research, China has improved the research on clarinet timbre techniques and the empirical research on music therapy, but the two research systems are separated from each other. The unique timbre characteristics of the clarinet have not yet been combined with the physical and mental healing experience of the public. There is a lack of targeted and refined instrumental therapy research.

2.2. Current Status of International Research

International clarinet research is more scientific, experimental and data-driven than domestic research, concentrating on the physical acoustics of the instrument, vibration mechanisms, spectral characteristics, environmental acoustic effects, and subjective quantitative perception of timbre, which constitutes a system of research in instrument acoustics.

In the area of timbre perception and environmental acoustics studies, Kato et al. employed a binaural room impulse response experiment to quantitatively investigate how hall reverberation, spatial acoustic environment, and sound field propagation conditions influenced the brightness, spectral distribution, and auditory quality of the clarinet timbre. They confirmed that although the external acoustic environment may slightly change the timbre details, the overall soft and stable timbre base of the clarinet remains unchanged and is suitable for various daily listening scenarios [7].

In the field of music neurotherapy research, Zhang et al. used a randomized single-blind blank control experiment and relied on EEG electroencephalography monitoring technology to carry out individualized music therapy pre-experiments. The study confirmed that continuous soft music listening can effectively activate the neural activity of the prefrontal cortex and central gyrus of the human brain, increase the spectral power of the alpha band of the brain, induce the brain to enter a relaxed resting state, and achieve safe, gentle, and effective emotional regulation and nerve soothing [8].

In terms of the research on the sound production mechanism of musical instruments, Darabundit and Scavone relied on the frontier port Hamiltonian system (PHS) framework to conduct modular acoustic modeling and time-domain simulation of the three core structures of the clarinet: reed, bore, and tone hole. Through the energy conservation algorithm, they verified that the clarinet sound production system has the acoustic characteristics of low energy consumption, high stability, and uniform vibration. From the perspective of physical acoustics, they scientifically explained the inherent acoustic advantages of the clarinet: pure and soft tone, no sharp high frequencies, and smooth and soothing listening experience [9]. This study clarified the physical origin of the clarinet's excellent tone and provided a solid acoustic theoretical support for its natural auditory healing advantages.

A comprehensive review of international research findings shows that the international academic community has fully confirmed that the clarinet possesses a high-quality, stable, and mellow acoustic timbre foundation, and that music auditory intervention has clear functions of neural regulation, emotional soothing, and physical and mental restoration. However, there is also a lack of specific research on the application of clarinet-specific timbre in physical and mental healing.

2.3. Research Review

A comprehensive review of existing research findings at home and abroad reveals that the academic community has accumulated a rich research foundation in the fields of clarinet timbre acoustics, performance aesthetics, empirical evidence of music therapy, and neurophysiological mechanisms. The current literature adequately acknowledges the artistic timbre value of the clarinet and physical and mental regulatory value of music auditory intervention. Nevertheless, there are still considerable gaps and deficiencies in the overall research:

To begin with, the research of clarinet has a one-sided approach, emphasizing mostly on stage performance and teaching techniques, ignoring the psychological value of the public and therapeutic role of independent timbre listening;

Second, music therapy studies are too general and broad, and frequently employ mixed musical materials, without specific and detailed studies of individual instruments and single timbres;

Third, current studies have not been able to systematically integrate the acoustic properties and auditory benefits of the clarinet with the emotional experience of the audience and psychosomatic control mechanisms;

Fourth, systematic research is lacking that would explain the therapeutic mechanism of instrumental timbre in a comprehensive way across various dimensions of physical acoustics, psychological perception and neurophysiology.

Based on the above research gaps, this paper, from a multidisciplinary perspective, systematically explores the auditory characteristics and psychosomatic therapeutic effects of clarinet timbre, making up for the deficiencies in existing research.

3. Acoustic Characteristics and Auditory Advantages of Clarinet Tone

3.1. Acoustic Mechanism of Clarinet Sound Production

The clarinet is a typical single-reed vibrating woodwind instrument. Its core sound production principle is that the reed is excited by the airflow to produce periodic vibration, which drives the air column inside the tube to resonate, forming continuous, stable, and regular sound waves that radiate outward. According to Darabundit's port Hamiltonian system modeling research, the overall acoustic structure of the clarinet has excellent modular energy conservation characteristics, the nonlinear coupling vibration of airflow and reed is uniform and stable, the sound energy loss of the tube is low and the numerical stability is strong[9].

Compared to woodwind instruments such as the flute and oboe, the clarinet has a gentle high-frequency harmonic decay rate, no sudden sharp spectral peaks, small fluctuations in sound wave output, strong regularity, and a uniform and soft overall spectral distribution. This special acoustic design enables the clarinet to inherently lack sharp, harsh and exciting auditory characteristics, creating a stable, soothing, warm and full timbre, which gives the clarinet its fundamental

physical acoustic basis of therapeutic role.

3.2. Core Auditory Advantages of Clarinet Tone

The therapeutic auditory benefits of the tone of the clarinet can be summed up in three points by integrating acoustic experiments and auditory aesthetic analysis:

To begin with, the tone is warm and pure, and the auditory stimulation is very low. The clarinet lacks high-frequency output (sharp) over its whole range and the amplitude of fluctuations in its sound wave is mild, not stimulating the auditory nerve strongly. Prolonged listening is less likely to cause auditory fatigue, psychological irritability, or emotional excitement, making it highly suitable for relaxing, stress-relieving, and calming listening scenarios.

Second, it has a full resonance layer and a strong auditory envelopment. The clarinet's air column resonates richly, resulting in a thick and delicate tone that creates a soft auditory envelopment effect, effectively weakening psychological tension and alienation, and possessing a strong emotional soothing effect.

Third, it has strong tonal stability and aligns with human body and mind rhythms. The clarinet's range transitions smoothly and naturally, and its sound wave vibration frequency is stable and regular, highly compatible with the breathing rhythm and brainwave rhythm of a person in a quiet and relaxed state, effectively guiding the body and mind into a relaxed state.

At the same time, combined with the acoustic experimental conclusions of Kato and Yasui, the clarinet has strong environmental adaptability, low distortion and high softness, and stable texture in daily indoor listening scenarios. It is a natural instrumental timbre that is suitable for the public's normal relaxed listening[1][7].

4. Mechanism of the clarinet tone in physical and mental healing

4.1. Psychological and emotional regulation mechanism

Emotional regulation is the most intuitive healing function of the clarinet tone. According to Liao Zhiliu's research conclusion, continuous, stable and gentle musical auditory stimulation can effectively relieve negative emotions such as anxiety, depression and irritability, enhance the individual's positive emotional experience, and enhance psychological resilience and stress coping ability[5]. The clarinet tone has no strong emotional fluctuations, no dramatic conflicts, and no sharp auditory stimulation. It can gently soothe emotional fluctuations, relieve mental tension, enhance auditory pleasure and psychological comfort, and achieve gradual repair and guidance of negative emotions.

4.2. Neurophysiological repair mechanism

From the perspective of neuroscience, the clarinet tone healing has a solid physiological scientific basis. Animal experiments by Chen Junrui et al. have confirmed that benign music stimulation can effectively inhibit central nervous system inflammation, reduce the level of systemic inflammation in the body, repair the neuronal structure damaged by stress, increase the number of Nissl bodies and dendritic spine density in the hippocampus, reshape the synaptic plasticity of the brain, and repair the nerve damage caused by psychological stress from a microscopic level [6].

At the same time, Zhang's EEG experiment further verified that listening to gentle and stable music can significantly increase the activity of the alpha frequency band in the brain. As the core brain wave in the human body's relaxed state, the alpha wave can directly play a role in calming the nerves, relieving fatigue, and soothing anxiety [8]. The clarinet has small timbre fluctuations, high stability, and a peaceful rhythm, which makes it easier to induce the brain to enter a benign relaxed state. Its neurotherapeutic suitability is far superior to that of exciting, bright, and fluctuating music timbre.

4.3. Aesthetic Empathy Healing Mechanism

The timbre of the clarinet is close to that of the human voice, natural, friendly, warm and simple, with a very high aesthetic acceptance, which can quickly trigger the audience's auditory aesthetic empathy. Under the effect of aesthetic empathy, individuals can effectively relieve psychological boredom, spiritual emptiness and emotional depression, and achieve spiritual comfort and psychological relaxation. Compared with musical works with strong drama and high emotional tension, the static, soft and stable timbre of the clarinet is more suitable for long-term normalized physical and mental relaxation healing.

5. Application Value of Clarinet Tone Healing

First, it is suitable for everyday relaxation and stress relief for the general public. Clarinet sound listening has a low barrier to entry, no side effects, and is suitable for a wide range of people. It can serve as a high-quality auditory resource for daily stress relief, pre-sleep relaxation, emotional calming, and fatigue relief, meeting the public's routine psychological health adjustment needs.

Second, application in campus psychological health education. Given the characteristics of students—high academic pressure, emotional sensitivity, and weak psychological resilience—clarinet sound listening can be incorporated into the campus art psychological counseling system to alleviate students' psychological pressure in an artistic way and enrich the forms of campus psychological health intervention.

Third, application in art rehabilitation. Leveraging the safe, gentle, and non-invasive auditory advantages of the clarinet sound, it can be applied to music therapy, physical and mental rehabilitation, and auxiliary intervention for emotional disorders, serving as a high-quality auxiliary means of art rehabilitation.

Fourth, broadening the scope of clarinet art applications. The extension of clarinet art beyond traditional stage performances and orchestral performances to the areas of public physical and mental health and art therapy significantly adds to the social practical and humanistic worth of clarinet instrumental art.

6. Conclusion

Drawing on literature review, theoretical analysis, synthesis of existing empirical findings and logical induction, this study investigates the auditory-perceptual characteristics of clarinet timbre and its mind-body therapeutic potential. Departing from the dominant performance-oriented paradigm in clarinet scholarship, the present work establishes a multi-disciplinary analytical framework that links acoustic

properties, auditory perception and psychophysiological responses. Its core theoretical contribution lies in unpacking the triple-path working mechanism of psychological-emotional regulation, neurophysiological modulation and aesthetic empathy, through which a single instrumental timbre exerts soothing effects. This research fills the niche gap between clarinet timbre acoustics and fine-grained instrumental music-therapy studies, two domains that have long remained isolated from one another.

The findings generate actionable practical implications for real-world implementation. Characterised by low auditory stimulation and stable spectral output, clarinet timbre can be developed into accessible, low-cost auditory resources for public daily stress mitigation and mood stabilisation, supporting unassisted routine mental-health self-regulation. Within campus mental-health services, clarinet-based auditory materials can be embedded into art-assisted psychological counselling, delivering a non-pharmacological supplementary approach to ease academic-driven anxiety among student groups. For art-rehabilitation contexts, this distinctive timbre offers a gentle acoustic alternative for assisting interventions targeting stress-related mental sub-health conditions.

Future work should advance empirical validation through large-sample controlled listening experiments, integrating subjective mood self-report scales and electroencephalogram recordings to quantify how performance-related variables such as register, dynamic level and articulation shape physiological relaxation indicators. Comparative perceptual tests against other woodwind instruments are also encouraged to isolate the unique therapeutic strengths of clarinet sound. Beyond laboratory settings, field trials within university counselling centres and community mental-health environments are necessary to examine practical effectiveness and contextual boundaries of timbre-centred auditory intervention, facilitating the translation of theoretical insights into workable therapeutic protocols.

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