A Study on the Living Heritage and Modern Choreography Integration of Mongolian Dance "Shoulder Shaking" and "Arm Flexibility" Techniques from the Perspective of Regional Culture

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ABSTRACT The Mongolian dance methods of shoulder shaking and arm flexibility have major issues of modern inheritance, such as an absence of standard movements, a loss of connection between the traditional approach and the aesthetic of modernity, driven by an over-reliance on static preservation that fails to adapt to contemporary visual languages, and a loss of acceptance by the younger generations. In this paper, the Field Investigation Method (FIM) is used to carry out in-depth interviews with 12 inheritors of intangible cultural heritage in Inner Mongolia and Xinjiang. Quantitative analysis of the frequency (2.8-3.5Hz) of shoulder-shaking and the parameters of trajectory (amplitude 18-22cm) of arm flexibility is done using Motion Capture Technology (MCT), building a three-dimensional teaching system: basic training, cultural awareness, and innovative practice. Comparative experiments show that the teaching group integrating modern choreography techniques achieved a technique mastery score of 82.9, a stage performance score of 76.3, and a cultural connotation recognition accuracy rate of 89.2%. The study proposes a living inheritance path of "core technique protection + aesthetic form innovation + digital recording," providing theoretical support and a practical paradigm that, while currently utilizing high-precision laboratory equipment, establishes a data-driven logic adaptable to low-cost consumer-grade wearable sensors and mobile vision systems for broader educational deployment. The motion-capture logic can be extended to wearable sensing when high-precision laboratory systems are unavailable.

INDEX TERMS mongolian dance, motion capture, living heritage, modern choreography, wearable motion sensing

I. INTRODUCTION

AS a physical representation of the grassland culture, Mongolian dance reflects the observation and imitation of nature by the nomadic people with its techniques of shoulder shaking and arm softening. Shoulder shaking is a technique that dates to the active capture of eagles fluttering and horses galloping, and transfers the visual image of flowing silk and waving water, expressing an idea of strength and passion in the vibration of the shoulder blades at a high frequency; arm softening is a technique that transfers the visual image of flowing silk and waving water, expressing the idea of grace and rhythm in the wave-like motion of the wr But the increased urbanization process has caused the breakup of the grassland life scenes and the young generation does not have any knowledge of the cultural symbols with which the techniques bear. The unification of movements has become more and more lost in the execution of oral and physical teaching, and we find in the performance of the same technique by various successors important deviations of the parameters of frequency and amplitude. The teaching of professional colleges emphasizes on stage effects, and undermines the strong bond between the techniques and ethnic culture, turning the shoulder shaking and arm softening into a set of formal movements, diminishing their kinetic vitality and expressive resonance [1,2]. Contemporary choreography is trying to implement electronic music and multimedia images in Mongolian dance productions, yet the fusion of the technique tends to get into the dilemma of the protection and the innovation. Instead of the continuation of traditions, overemphasis on tradition results in old-fashioned aesthetics and an unceasing drop in the popularity among the young audience; instead of radical modernization, the techniques are deprived of the cultural essence, which leaves them in question on behalf of the heirs. The absence of quantitative norms leaves the transmission of techniques to

subjective experience and judgment and thus it is impossible to develop a paradigm of teaching that can be replicated. Motion capture, virtual reality, and other digital technologies applied to the sphere of ethnic dance remain in the exploration phase, and while generic applications remain in the exploration phase, a standardized, multi-dimensional framework for systemic pedagogical integration has yet to be empirically validated [3,4]. The proposed study also concentrates on the quantitative analysis coupled with the creation of the mechanism of a living inheritance of the techniques of "shoulder shaking and arm softening exploring the possibility of sustainable development by balancing between cultural protection and aesthetic innovation, and offering practical solutions addressing the survival of the ethnic dance in a modern context.

II. RELATED WORK

The study of the inheritance of ethnic dance skills has been long concerned with the interpretation of the ritual functions and symbolic meanings based on the cultural anthropological approach, that is, the importance of oral history collection and field ethnography in disentangling the lineage of skills. Academic community mostly accepts that the living inheritance must react to the social changes, but preserve the authenticity of skills, although the definition of authenticity is a matter of controversy. Other research identifies solidification of movement forms with cultural protection disregarding the flexibility and development capability that skills, a dynamic culture, should possess. Technical specifications (image recording and 3D scanning) have been developed in the area of digital protection of intangible cultural heritage, although the majority of them are still at the stage of the passive construction of the archive and have not yet succeeded in converting digital outcomes into a dynamic resource that may be utilized in the educational process and handed down [5,6]. Motion capture technology has been successful in the accurate quantification of kinematic parameters in sports training and rehabilitation medicine, but has not been used to quantitatively measure the properties of typical ethnic dance techniques and has primarily been used to analyse the movement aspects of Western dance styles, including ballet and modern dance. Current literature is based on a multitude of adjectives describing techniques like shoulder shaking and arm flexibility without measurable parameters that include frequency, amplitude and angular velocity, resulting in imprecise technical criteria. Practical experiments of the integration of traditional dance and modern choreography are also largely founded on the personal creative experience of choreographers and are not systematically designed and not tested on the level of teaching system. Despite the importance of cultural awareness education, some studies have not given particular implementation directions nor a system of evaluation indices of the integration effect. The use of digital technology in the teaching of inheritance is still on the level of the auxiliary demonstration and the mechanism of impact of the virtual reality environment on the learning outcomes is not completely discovered.

III. METHODS

A. IMPLEMENTATION PATH AND DATA COLLECTION OF FIELD SURVEY METHOD

The project was a 10-month in-depth field survey in Hohhot and Tongliao, Inner Mongolia, and Bortala Mongol Autonomous Prefectures, Xinjiang, between March 2024 and January 2025. The respondents of the survey were 12 representatives of the inheritance of the Mongolian dance intangible cultural heritage aged 45-78 with over 30 years of dancing experience. A mix of semi-structured interview approach was used where each inheritor was interviewed between 120 and 180 minutes, and questions were directed towards power generation technique of shoulder shaking, the movement pattern of scapula, the breathing rhythm, the technical specifications of certain elements of the soft arm, including the angle of a wrist rotation, the range of flexion and extension of the elbow, and the control of force of the fingertips. The demonstration movements of the inheritors were filmed with use of high-definition video devices on three angles: front, side, and top, which resulted in 1847 minutes of raw video data. A coding system of skill description was developed and validated using the Delphi method with a secondary expert panel, and the oral material was classified... creating a database of 216 movements segments selected based on their representation of peak kinematic variance between the bold Horqin style and the fluid Chahar style[7,8]. This study was approved by the Ethics Committee of Tai Shan University, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

B. QUANTITATIVE ANALYSIS FRAMEWORK FOR MOTION CAPTURE TECHNOLOGY

It utilized the OptiTrack Prime series optical motion capture system, and installed 12 infrared cameras in a 4m×6m performance space with a capture rate of 240 frames per second. Reflective marker balls that had a diameter of 14 mm were fixed on 23 anatomical landmarks such as the acromion, inferior angle of the scapula, elbow joint, wrist joint, and fingertips of the dancers. The vertical displacement curve of the shoulder markers was extracted by the "shoulder shaking" motion analysis. Fast fourier transform was used to determine the main frequency component. The frequency of shaking of the Horqin style was found to be clustered at the range of 3.2-3.5 Hz and the frequency of the Chahar style was 2.8-3.1 Hz. The quantitative collection of the three-dimensional space coordinates of the wrist markers was done in the technique of the soft arm. The movement path was computed by computing the difference between successive frames. The peak to trough amplitude was found to be 18-22 cm vertically and the horizontal extension distance was 32-38 cm [9,10]. The angle of the upper arm and forearm marker points are used to determine

the elbow flexion and extension angle. The angle in normal flexible arm movement is between 95 and 165 degrees and the time taken by the arm to complete a wave cycle is 1.8-2.3 seconds. The system automatically creates time-series data with displacement, velocity and acceleration, and it is exported as a C3D file to perform in-depth analysis of the joint torque properties with the biomechanical software Visual3D.

C. CONSTRUCTION METHODS OF THREE-DIMENSIONAL TEACHING SYSTEM

The basic training module divides the shoulder shaking technique into three levels of progression: trapezius muscle activity, scapular coordination and the breathing rhythm coincidence. Electromyography (EMG) sensors are put on trainees to measure the amplitude of discharge of upper trapezius muscle, which should be 60-75 percent of the maximum voluntary contraction, before they are allowed to move to the next training unit. The training design of the flexible arm includes the continuous exercises of the wrist circles, the movements with the elbow as their head and the shoulder extension. Laser projection is used to draw a standard movement path on the ground; an audio signal is sounded when the trainee wrists move beyond 5 centimeters of the direction of the movement path. The cultural awareness module presents video content of Mongolian shamanic rituals and Naadam festival, discussing the cultural symbolism of the shaking of shoulders which mimics the wingspan of an eagle and the flexing of the arm which is a symbol of silk flowing. Trainees go through 12 observation logs describing the relationship between the movements and the grassland life scenes. The innovative practice module overlays the electronic music rhythms with the melody of morin khuur (horsehead fiddle) and trains the trainees to keep the shoulder shaking frequency at 3.0 Hz by modifying the amplitude of the movement to suit the beat of the modern 120 beats per minute. A simulated VR rehearsal space was created and trainees in HTC Vive headsets finished their choreographed pieces in a virtual grassland. Their movement parameters were compared with the database of inheritors in real time by the system.

D. COMPARATIVE EXPERIMENTAL DESIGN AND EVALUATION INDEX SYSTEM

A total of 68 dance students were recruited and balanced to form an experimental and a control group of 34 each with respect to gender, dance experience and physical condition. The control group was provided with a single teaching model of oral instruction by inheritors, 16 weeks with 6 classes each week. The experimental group embraced a three-dimensional instructional framework that incorporated the training of motion capture feedbacks and the cultural immersion learning and the practice of virtual reality choreography as part of the identical class timetable. The art of techniques was evaluated by a panel of experts, including three inheritors of intangible cultural heritage, who rated students according to four criteria: stability of shoulder shaking frequency, arm movement trajectory consistency, smoothness, and joint coordination precision, with an equal number of points (25) on each. The performance of the stages was considered by asking 120 audience to view 3-minute clips of solo dances by both sets of students and rating them on the aspects of expressiveness of movement, conveying emotion, use of space, and controlling of rhythm using a 100-point scale. Cultural connotation recognition test played 15 video clips of dances of the Mongols in various regions. The correct recognition of the life scenes, emotional meanings, and regional affiliations, which were conveyed by the movements, were required of the students; this was a quantitative measure of the accuracy rate. To measure heart rate variability during training, which depicts the degree of physical and mental coordination of the trainees, a Polar H10 heart rate monitor was used to measure physiological indicators.

IV. RESULTS AND DISCUSSION

A. QUANTITATIVE CHARACTERISTICS ANALYSIS OF "SHOULDER SHAKING" AND "ARM SOFTENING" TECHNIQUES

Motion capture data was extracted from 216 action segments, and 142 typical samples that met the criteria for inheritor recognition were selected. The skill parameters of the three schools of Khorchin, Chahar, and Oirat were archived separately, and descriptive statistics and analysis of variance were performed using SPSS 26.0 software, as shown in Table 1.

TABLE 1. Comparison of Quantitative Parameters of "Shoulder Shaking" and "Arm Softening" Techniques from Different Schools

School	Shoulder shaking frequency (Hz)	Shoulder displacement (cm)	Flexible arm amplitude (cm)	Elbow joint angular velocity (°/s)
Horqin	3.35 ± 0.12	4.2 ± 0.6	19.7 ± 1.4	71.3 ± 5.8
Chahar	2.95 ± 0.15	3.1 ± 0.5	18.3 ± 1.1	65.2 ± 6.2
Vilat	3.18 ± 0.14	3.8 ± 0.7	21.8 ± 1.6	69.8 ± 5.4

The average frequency of "shoulder shaking" movement in Horqin school was 3.35 Hz, which was obviously higher than that (2.95 Hz) in Chahar school. The shoulder vertical displacement was 4.2 cm. In the technique of "soft arm", the wrist trajectory amplitude of Weilat school was the largest (21.8 cm), and the amplitude of Chahar school (which focused on delicate control) was only 18.3 cm. The elbow flexion and extension angular velocity data showed that when the standard soft arm wave movement was completed at the extension angle of 135 degrees, the angular velocity of flexion and extension reached the maximum, and the average value was 68.7 degrees/s. The "shoulder shaking" frequency of different schools was significantly different. The morphology similarity of "soft arm" wrist and elbow trajectory in different regions was 0.87, which was high. The repeatability of 12 inheritors showed that the intra-individual coefficient of variation was less than 8.3%.

B. EVALUATION OF THE IMPLEMENTATION EFFECTIVENESS OF THE THREE-DIMENSIONAL TEACHING SYSTEM

Following a 16-week teaching cycle, extensive assessment was done on 68 trainees in experimental and control groups. The mastery of techniques was evaluated by an expert panel alone, and the average score was obtained. Experiment: Stage presence was tested at a professional theater using anonymous audience scoring. Cultural understanding was assessed by a standardized question bank. Paired-samples t-tests were used to analyze the significance of differences between groups after data collection. The results are shown in Table 2.

TABLE 2. Comparison of teaching effects between the experimental group and the control group

Evaluation indicators	Experimental group (n=34)	Control group (n=34)	Increase	p-value
Mastery of technique (points)	82.9 ± 6.3	69.4 ± 7.8	41.3%	< 0.001
Stage presence (points)	76.3 ± 8.1	52.1 ± 9.4	46.5%	< 0.001
Culture recognition accuracy (%)	89.2 ± 5.6	64.7 ± 8.2	37.8%	< 0.001
Heart rate variability RMSSD (ms)	68.4 ± 11.2	51.2 ± 9.8	33.6%	< 0.01

The results detailed in Table 2 demonstrate a significant divergence in learning outcomes; specifically, the skill mastery score of the experimental group reached 82.9 points. Conversely, the control group demonstrated limited progression, increasing from 57.9 points to a mere 69.4 points, thereby underscoring a substantial statistical gap between the two pedagogical approaches. In terms of stage presence, the experimental group scored 76.3 points, which was 46.5% more than that of the control group (52.1 points). This disparity suggests that while the inheritors possess profound mastery, the traditional 'oral-and-physical' transmission model alone struggles to bridge the cognitive gap for modern students within a limited 16-week timeframe, compared to augmented digital feedback. In addition, most of the audience members also believed that the experimental group's movements were much better in both their coordination with the music and their expression of emotions. The experimental group reached 89.2% accuracy in recognizing the cultural connotations of the skills, while the control group only reached 64.7%. This shows that the three-dimensional teaching system can help students better understand the key cultural connotations of the skills. As shown in Table 3, the RMSSD value of the experimental group was 68.4 milliseconds, while that of the control group was 51.2 milliseconds. The experimental group had stronger activity of the parasympathetic nerve, reflecting enhanced mental focus and emotional regulation rather than reduced physical demand, as both groups maintained equivalent metabolic equivalents (METs) during their respective training sessions.

C. VERIFICATION OF THE INHERITANCE PATH INTEGRATING MODERN CREATION

The highest completion rate of the choreographed works in the experimental group were tested on the path verification analysis (eighteen works). Invited were a judging panel, made up of six intangible cultural heritage inheritors and eight modern dance choreographers and 120 general audience members. The pieces were rated on three dimensions, which included: technique retention, aesthetic innovation, and digital presentation effect with each of the dimensions rated out of 100. The retention of technique was observed, by drawing comparisons between the frequency and the path of the movements of the shoulder shaking and arm flexibility along with the deviation value of the inheritor database. Aesthetic innovation was determined through the contemporary significance of music selection, spatial composition and costume design. Digital presentation effect was quantified by assessing the immersive experience of the virtual reality scene and quality of visualization of the motion capture data. The results are shown in Table 3.

TABLE 3. Comparison of Evaluation Results for Works from Different Inheritance Paths

Inheritance path types	Technique retention rate (points)	Aesthetic innovation (score)	Digital presentation (points)	Audience acceptance (%)
Fusion paths (n=18)	91.7 ± 4.2	85.3 ± 6.7	88.6 ± 5.4	87.9
Single lineage (n=16)	94.2 ± 3.1	61.8 ± 8.9	52.3 ± 11.2	47.3
Over-innovation (n=12)	73.5 ± 9.6	91.2 ± 4.8	79.4 ± 7.3	68.6

Works employing the "core technique preservation + aesthetic form innovation + digital recording" approach achieved an average technique preservation score of 91.7, with a shoulder-shaking frequency deviation of only 0.18 Hz and a similarity of 0.93 for arm trajectories. Aesthetic innovation scored 85.3, with inheritors acknowledging its preservation of the essence of grassland culture while incorporating electronic sound effects and light and shadow art. Digital presentation scored 88.6, the virtual grassland environment's realism was rated 4.6, and the audience immersion questionnaire score was 82.1. In contrast, works using a single inheritance model, while achieving a technique preservation score of 94.2, only scored 61.8 in aesthetic innovation, and a survey of young audience acceptance showed that only 47.3% were willing to watch them a second time.

V. CONCLUSION

Quantitative Characterization Analysis of Mongolian Dance Techniques of "Shoulder Shaking" and "Arm Flexibility". Different frequency and trajectory characteristics of Mongolian dance techniques of "Shoulder Shaking" and "Arm Flexibility" in different major styles are found. Motion Capture. An operational model for the digital archiving of the technique of "Shoulder Shaking" and "Arm Flexibility" is established. Three-Dimensional Teaching System. The single form of "oral transmission" is broken through, and the fact that students can improve their level of technique mastery and stage tension virtual reality choreography is obvious. Based on the three-dimensional teaching system, "core technique protection + aesthetic form innovation + digital recording" improves the recognition of young people

while standardizing the technique, which provides a solution for the living inheritance of ethnic dance that grasps the cultural core and pursues contemporary aesthetics. This study only includes three major styles, and the three major styles do not include the variation of techniques in regions, Xilin Gol and Alashan. In the future, we should extend the range of field investigation, build a movement database of more styles, and explore the possibility of using AI-assisted personalized teaching model, so as to promote the transformation of technique inheritance experience into data.

AUTHOR CONTRIBUTIONS

Qian Chen designed, collected and analyzed the data, and drafted the manuscript. Qian Chen conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Qian Chen 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 Tai Shan University, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

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